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Analysis of Linkage for Ten X-STR Markers in a Rio de Janeiro (Brazil) Three-Generation Family Sample

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Abstract

Recently, typing of polymorphisms on the X chromosome has become a standard technique in forensic genetics and a growing number of short tandem repeats (STR) has been established in this chromosome related to genetic population studies. Knowledge of marker recombination is very important especially when the X chromosome typing is used in forensic kinship analysis. It is known that the meiotic recombination is not a simple function of the physical distance between segments of the DNA but the recombination events between them tend to be clustered at special regions of the chromosome. Information on the rate of recombination among markers can be gathered by studying families through several generations. In this work we have typed DNA samples of pedigree consisting of nineteen families in Rio de Janeiro, constituted of grandfather, mother and grandson, and in some cases grandmother and aunt, and reported the recombination of 10 STR markers of the X chromosome. The study of the linkage analysis using the LOD score has shown that the marker pairs DXS8378-DXS7423, DXS7132-DXS9898, DXS7132-GATA172D05 DXS9898-DXS7133 and DXS6809-DXS7133 are not transmitted in a random way, during a recombination event.

Keywords

X-Chromosome STR Markers, Recombination, Probability of Linkage, LOD Score

1. Introduction

The benchmark of using the X chromosome markers in the forensic practice can be found in the clinical genetics

around the years 1950. The haemophilia and the red-green blindness, for example, are diseases caused by the recessive genes linked to the X chromosome. As the women inherit two X chromosomes, they may be homozygote for the recessive allele, therefore the allele related to the disease is doubled, heterozygote or homozygote for the normal and dominant alleles at this locus. In women the disease happens when they have recessive alleles for the disease gene in homozygose, while in men, due to the X chromosome hemyzigose, happens with only one recessive allele at this locus [1].

If the disease carrier is a fertile male patient, his daughters will always inherit the defectfull X chromosome. Consequently, the daughters will transmit with 50% of probability to next generation. Such paternal heritage pattern of the X chromosome to his daughters has become an additional method of using the X chromosome markers in the genetic kinship analysis.

Besides, if a man has two or more X chromosome alleles linked physically it is obvious that these alleles must be unified in a haplotype. In the context of forensic analysis, the challenge is the stablishment of methods that can bypass the relative deficiency in the kinship testings. A possibility is to use X chromosome markers haplotypes. The method of substituting the individual STR markers by haplotypes can furnish useful tools when it is applied to kinship testing for individuals of the female gender. This is the reason of the importance of the analysis of linkage of X-STR markers using the LOD score [2].

The Brazilian population was formed by successive migratory waves. The Amerindian people were occupying the Brazilian territory when the Portuguese arrived in 1500, and colonized the country. Between the 16th and the 19th centuries Africans were brought to Brazil as slaves, and besides the Portuguese, other migratory waves occurred in the 19th and 20th centuries, mainly from Italy, Germany and Spain. All these migratory events have contributed to the formation of a multiethnic highly mixed population. This heterogeneity is due to the nonuniform triethnic (European + African + Amerindian) pattern for the Brazilian population gene pool [3].

2. Materials and Methods

A population sample of 19 families, whose individuals are unrelated from each other, was selected from the population of the Brazilian state Rio de Janeiro with 45 males and 23 females.

2.1. X-STR Amplification

For the PCR amplification of the target loci we used pairs of primers in a decaplex system [4], the QIAGEN Multiplex PCR Kit, at 1× QIAGEN multiplex PCR master mix, mix of primers at concentration of 0.2 μM and 1 - 2 ng of DNA, in a final volume of 6.5 to 10 μL. Primers were fluorescent labeled with 6-FAM (DXS8378, DXS9898, DXS7133, GATA31E08), with VIC (GATA172D05, DXS7423, DXS6809) and with NED (DXS 7132, DXS9902, DXS6789) (see **Table 1**, **Table 2** and **Figure 1**).

Thermocycling conditions were: pre-incubation for 15 min at 95˚C, followed by ten cycles of 30 s at 94˚C, 90 s at 60˚C, 60 s at 72˚C; and 20 cycles of 30 s at 94˚C, 90 s at 58˚C, and 60 s at 72˚C with a final incubation for 60 min at 72˚C [4].

2.2. Analysis of PCR Products

Aliquots of 1 mL of PCR product were mixed with 8.8 mL formamide and 0.2 mL of ILS 500 size standard (Applied Biosystem) and separated by capillary electrophoresis on an ABI Prism 3130 Avant Genetic Analyzer instrument with denaturing polymer 3100 POP-7TM (Performance Optimized Polymer-Applied Biosystems) with GeneMapper v 3.01 Analysis Software (Applied Biosystems). In the **Appendix A** we present all the X-STR typing of all the families.

In order to determine if two loci are linked we must use the following procedure: (a) Typing the X chromosome markers of the families with grandfather, mother and grandson; (b) Counting the number of children that shows or does not show recombination between these two loci; (c) Calculating the LOD score using the equation (1); (d) Maximizing the Equation (1) in order to find θ_{max}; (e) Finally, obtaining $Z_{max} = Z(\theta_{max})$. The LOD score is given by

$$Z = \log_{10}\left[\frac{\theta^m (1-\theta)^n}{(1/2)^m (1/2)^n}\right] = \log_{10}\left[2^m 2^n \theta^m (1-\theta)^n\right] \qquad (1)$$

Table 1. Sequence of the primers of the decaplex system [4].

LOCUS	PRIMERS (5' - 3')
DXS8378	CACAGGAGGTTTGACCTGTT
	AACTGAGATGGTGCCACTGA
DXS9902	TGGAGTCTCTGGGTGAAGAG
	CAGGAGTATGGGATCACCAG
DXS7132	TGATTAGGAATATCAAAGGCAAA
	CTTCTCTGGTTCTCTAGCTCACAT
DXS9898	CGAGCACACCTACAAAAGCT
	TCGATTAGGTTCAGTTCCCA
DXS6809	TGAACCTTCCTAGCTCAGGA
	TCTGGAGAATCCAATTTTGC
DXS6789	TTGGTACTTAATAAACCCTCTTTT
	CTAGAGGGACAGAACCAATAGG
DXS7133	GCTTCCTTAGATGGCATTCA
	CTTCCAAGAATCAGAAGTCTCC
GATA172D05	TAGTGGTGATGGTTGCACAG
	ATAATTGAAAGCCCGGATTC
GATA31E08	AGGGGAGAAGGCTAGAATGA
	CAGCTGACAGAGCACAGAGA
DXS7423	GTCTTCCTGTCATCTCCCAAC
	TAGCTTAGCGCCTGGCACATA

Table 2. The identification locus number.

#	Locus	Xp-tel Distance
1	DXS8378	9330
2	DXS9902	15233
3	DXS7132	64572
4	DXS9898	87682
5	DXS6809	90180
6	DXS6789	95336
7	DXS7133	108928
8	GATA172D05	113061
9	GATA31E08	140800
10	DXS7423	149461

Note: The distances from Xp-telomere (Xp-tel) are in unites of 1000 base pairs.

where θ is the recombination frequency, m is the number of meiosis when recombination happens e n is the number of meiosis when recombination between the two loci does not happen [5]. In the **Appendix B** we present the detailed linkage analysis for all the families.

3. Results and Discussion

The study of the linkage analysis between two loci using the LOD score has shown (see **Table 3**) that the marker pairs DXS8378-DXS7423, DXS7132-DXS9898, DXS7132-GATA172D05, DXS9898-DXS7133 and DXS6809-DXS7133 are linked during a crossing over event. Their LOD scores are greater or equal to three, *i.e.*, they are at least a thousand times greater than the probability of a transmition of the alleles in a random way.

Table 3. The total maximum LOD scores are listed. The total is the sum of the LOD of the 19 families. Significant scores (≥ 3) are denoted by the symbol.

Combination of Markers	$Z_{max}^{(total)}$
DXS8378-DXS9902	2.54
DXS8378-DXS7132	2.70
DXS8378-DXS9898	2.17
DXS8378-DXS6809	2.10
DXS8378-DXS6789	1.80
DXS8378-DXS7133	2.40
DXS8378-GATA172D05	2.40
DXS8378-GATA31E08	2.70
DXS8378-DXS7423	*3.30
DXS9902-DXS7132	1.80
DXS9902-DXS9898	1.80
DXS9902-DXS6809	2.40
DXS9902-DXS6789	1.87
DXS9902-DXS7133	2.17
DXS9902-GATA172D05	2.10
DXS9902-GATA31E08	2.47
DXS9902-DXS7423	2.17
DXS7132-DXS9898	*3.00
DXS7132-DXS6809	2.70
DXS7132-DXS6789	2.70
DXS7132-DXS7133	2.40
DXS7132-GATA172D05	*3.00
DXS7132-GATA31E08	2.47
DXS7132-DXS7423	2.77
DXS9898-DXS6809	2.40
DXS9898-DXS6789	2.70
DXS9898-DXS7133	*3.00
DXS9898-GATA172D05	2.70
DXS9898-GATA31E08	1.87
DXS9898-DXS7423	2.17
DXS6809-DXS6789	2.40
DXS6809-DXS7133	*3.00
DXS6809-GATA172D05	2.40
DXS6809-GATA31E08	2.10
DXS6809-DXS7423	2.40
DXS6789-DXS7133	1.80
DXS6789-GATA172D05	2.40
DXS6789-GATA31E08	1.80
DXS6789-DXS7423	2.10
DXS7133-GATA172D05	2.10
DXS7133-GATA31E08	1.80
DXS7133-DXS7423	2.10
GATA172D05-GATA31E08	2.40
GATA172D05-DXS7423	2.70

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BLOOD OR SWAB          DNA EXTRACTION  BY        DETERMINATION  OF
SAMPLES         →      SALTING–OUT METHOD    →   CONCENTRATION OF
OF THE GP, M, GS                                 2 ng OF DNA USING
                                                 ESPECTROPHOTOMETRY
                                                         ↓
                                                 STR AMPLIFICATION
                                                 USING DECAPLEX
                                                 SYSTEM  [3]
                                                         ↓
ANALYSIS OF            ALLELES OBTAINED          ANALYSIS OF PCR
LINKAGE OF THE         USING THE ABI             PRODUCTS USING
ALLELES USING    ←     ANALYSIS SOFTWARE   ←     CAPILLARY
L OD SCO RE  [4]       GE NE MAPPER   3.01       ELECTROPHORESIS
                                                 ON ABI PRI  SM 3130
```
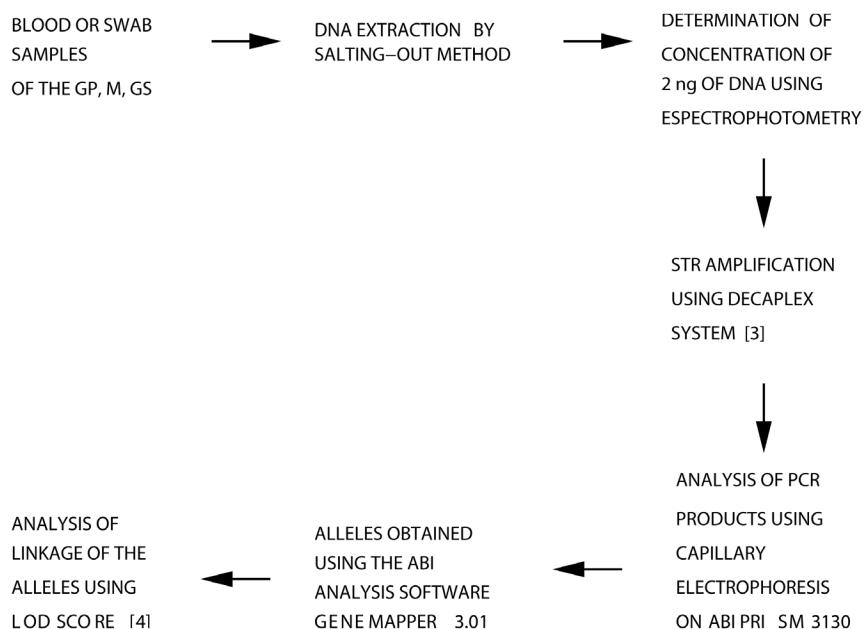
Figure 1. Flow chart depicting the process of obtaining the STR alleles of the X chromosome and the linkage analysis between them.

In a recent work Hering and collaborators [2], using 3-generation families and 39 X-STRs, have studied four clusters of closely localized marker linkage groups: (I) DXS10148-DXS8378 at Xp21, (II) DXS7132-DXS981 at Xq12, (III) DXS10103-DXS10101 at Xq26 and (IV) DXS10146-DXS10011 at Xq28. They have found that there was independent segregation between linkage groups I/II and II/III. The genetic distance between groups III and IV was found to be too small to assume independence. Notice that in this work we have only two coincident markers (DXS8378 and DXS7132) and they are located in the linkage groups with independent segregation.

Finally, this work is the first one in the literature that shows this kind of linkage analysis for recombination in X-chromosome STRs, using a sample of families from Rio de Janeiro (Brazil).

Acknowledgments

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Appendix A

In this appendix we present the **Table 4** with the alleles of each member of the families.

Table 4. Typing of the X chromosome of families 1 to 19.

Family 1				
#	GP	M	M	GS
1	11	11	9	11
2	13	13	12	*12
3	14	14	12	14
4	8.3	8.3	7	*7
5	31	31	36	*36
6	20	20	15	*15
7	11	11	9	*9
8	8	8	9	*9
9	13	13	9	*9
10	14	14	11	14

Family 2				
#	GP	M	M	GS
1	10	10	12	10
2	11	11	12	11
3	13	13	14	13
4	8.3	8.3	11	8.3
5	33	33	34.1	33
6	25	25	20	*20
7	10	10	9	*9
8	9	9	10	*10
9	11	11	13	*13
10	14	14	16	*16

Family 3				
#	GP	M	M	GS
1	11	11	11	11
2	11	11	8	11
3	15	15	13	15
4	10	10	14	10
5	33	33	34	33
6	21	21	19	21
7	10	10	14	10
8	9	9	6	9
9	9	9	11	*11
10	14	14	15	*15

Family 4

#	GP	M	M	GS
1	10	10	10	10
2	11	11	11	11
3	14	14	14	14
4	12	12	8.3	12
5	31	31	33	31
6	20	20	20	20
7	10	10	9	10
8	6	6	10	6
9	12	12	11	12
10	14	14	14	14

Family 5

#	GP	M	M	GS 1	GS 2	GS 3
1	10	10	11	*11	10	*11
2	11	11	12	*12	*12	*12
3	14	14	14	14	14	14
4	12	12	12	12	12	12
5	31	31	31	31	31	31
6	20	20	20	20	20	20
7	10	10	10	10	10	10
8	6	6	10	6	6	6
9	12	12	11	12	12	12
10	14	14	16	*16	*16	*16

Family 6

#	GP	M	M	GS
1	10	10	11	*11
2	11	11	12	*12
3	14	14	14	14
4	8.3	8.3	13	*13
5	34	34	34	34
6	20	20	21	*21
7	9	9	9	9
8	8	8	11	*11
9	9	9	11	*11
10	15	15	15	15

Family 7				
#	GP	M	M	GS
1	12	12	12	12
2	13	13	11	13
3	14	14	14	14
4	11	11	11	11
5	32	32	34	32
6	20	20	22	20
7	9	9	11	9
8	11	11	9	11
9	11	11	12	*12
10	15	15	15	15

Family 8					
#	GP	M	M	GS 1	GS 2
1	11	11	12	11	*12
2	12	12	12	12	12
3	17	17	14	*14	*14
4	11	11	13	*13	*13
5	33	33	33	33	33
6	22	22	11	*21	*21
7	9	9	9	9	9
8	12	12	11	*11	*11
9	13	13	13	13	13
10	14	14	15	14	*15

Family 9						
#	GP	M	M	GS 1	GS 2	GS 3
1	10	10	10	10	10	10
2	12	12	13	12	*13	12
3	15	15	12	*12	*12	*12
4	13	13	14	*14	*14	*14
5	31	31	33	*33	*33	*33
6	21	21	20	*20	*20	*20
7	11	11	11	11	11	11
8	10	10	11	*11	*11	*11
9	13	12	11	*11	*12	*11
10	14	14	13	*13	14	*13

Family 10				
#	GP	M	M	GS
1	11	11	10	11
2	11	11	12	11
3	14	14	13	14
4	8.3	8.3	8.3	8.3
5	33	33	33	33
6	22	22	20	22
7	12	12	11	12
8	6	6	10	6
9	12	12	13	12
10	15	15	14	15

Family 11				
#	GP	M	M	GS
1	10	10	10	10
2	11	11	9	11
3	15	15	12	*12
4	13	13	12	*12
5	33	33	35	*35
6	21	21	20	*20
7	9	9	11	*11
8	6	6	9	6
9	12	12	12	12
10	14	14	16	14

Family 12							
#	GP	GM	GM	M	M	A	A	GS
1	10	10	12	10	12	10	10	*12
2	11	12	12	11	12	11	12	*12
3	14	13	13	14	13	14	13	14
4	14	8.3	13	14	13	14	8.3	14
5	31	30	33	31	30	31	30	31
6	22	20	23	22	23	22	22	22
7	9	9	9	9	9	9	9	9
8	8	10	10	8	10	8	10	8
9	13	12	14	13	12	13	15	*12
10	15	14	15	14	15	15	15	15

Family 13							
#	GP	GM	GM	M	M	A	A	GS
1	10	10	12	10	10	10	10	10
2	11	12	12	11	12	11	12	*12
3	14	13	13	14	13	13	14	14
4	14	8.3	13	14	13	8.3	14	14
5	31	30	33	31	33	30	31	31
6	22	20	23	22	20	22	22	22
7	11	12	12	11	12	9	9	*12
8	8	10	10	8	10	8	10	8
9	13	12	14	13	14	12	13	13
10	15	14	15	14	15	15	15	15

Family 14				
#	GP	M	M	GS
1	10	10	12	*12
2	11	11	12	*12
3	13	13	14	13
4	13	13	12	13
5	32	32	33	*33
6	20	20	22	20
7	12	12	9	12
8	8	8	11	8
9	12	12	9	12
10	15	15	15	15

Family 15				
#	GP	M	M	GS
1	10	10	11	10
2	11	11	12	11
3	13	13	14	13
4	13	13	12	*12
5	32	32	33	*33
6	20	20	22	*22
7	12	12	9	*9
8	8	8	11	8
9	12	12	14	12
10	15	15	14	15

Family 16				
#	GP	M	M	GS
1	10	10	12	*12
2	11	11	12	*12
3	13	13	15	13
4	13	13	13	13
5	32	32	36	*36
6	20	20	20	20
7	12	12	9	*9
8	8	8	8	8
9	12	12	14	12
10	15	15	14	*14

Family 17				
#	GP	M	M	GS
1	10	10	11	10
2	11	11	11	11
3	14	14	13	14
4	12	12	11	12
5	31	31	29	31
6	21	21	24	21
7	10	10	11	10
8	8	8	10	8
9	13	13	13	13
10	14	14	15	14

Family 18				
#	GP	M	M	GS
1	11	11	10	*10
2	12	12	12.1	12
3	13	13	14	*14
4	11	11	8.3	*8.3
5	35	35	33	*33
6	20	20	20	20
7	9	9	11	*11
8	11	11	10	*10
9	13	13	13	13
10	15	15	13	15

Family 19						
#	GP	M	M	GS 1	GS 2	GS 3
1	11	11	10	11	11	11
2	13	13	11	13	13	*11
3	13	13	14	*14	13	*14
4	8.3	8.3	11	*11	8.3	8.3
5	33	33	34	*34	*34	*34
6	19	19	20	*20	*20	19
7	9	9	11	*11	*11	9
8	11	11	6	*6	*6	11
9	15	15	9	15	15	15
10	16	16	15	16	16	16

Note: The symbols GP, M and GS denote the grandfather's, mother's and grandson's alleles, respectively. The symbol * means that there is crossing over between the two mother's alleles. In the Families 12 and 13, the GP's alleles are reconstituted from the GM's, M's and A's alleles. The symbols GM and A denote grandmother's and aunt's alleles, respectively.

Appendix B

In this appendix we present the Tables 5-23 with the detailed linkage analysis of each family.

Table 5. Linkage analysis of family 1.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(1)}$
1 - 2	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
1 - 3	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
1 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
1 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
1 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
1 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
1 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
1 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
1 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
2 - 3	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
2 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
2 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
2 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
2 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
2 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
2 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
2 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
3 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
3 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
3 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
3 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
3 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
3 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
3 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
4 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
4 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
4 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
4 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
4 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
4 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0

Continued

5 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
8 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
8 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0

Table 6. Linkage analysis of family 2.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(2)}$
1 - 2	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 3	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 3	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0

Continued

3 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
8 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
8 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0

Table 7. Linkage analysis of family 3.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(3)}$
1 - 2	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 3	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30

Continued

1 - 7	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
1 - 8	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
1 - 9	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
1 - 10	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
2 - 3	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
2 - 4	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
2 - 5	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
2 - 6	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
2 - 7	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
2 - 8	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
2 - 9	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
2 - 10	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
3 - 4	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
3 - 5	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
3 - 6	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
3 - 7	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
3 - 8	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
3 - 9	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
3 - 10	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
4 - 5	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
4 - 6	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
4 - 7	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
4 - 8	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
4 - 9	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
4 - 10	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
5 - 6	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
5 - 7	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
5 - 8	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
5 - 9	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
5 - 10	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
6 - 7	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
6 - 8	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
6 - 9	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
6 - 10	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0

Continued

7 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
7 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
8 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
8 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0

Table 8. Linkage analysis of family 4.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(4)}$
1 - 2	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 3	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 3	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30

Continued

4 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
7 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
7 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
7 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
8 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
8 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30

Table 9. Linkage analysis of family 5.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(5)}$
1 - 2	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
1 - 3	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0
1 - 4	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0
1 - 5	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0
1 - 6	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0
1 - 7	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0
1 - 8	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0
1 - 9	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0
1 - 10	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
2 - 3	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
2 - 4	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
2 - 5	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
2 - 6	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0

Continued

2 - 7	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
2 - 8	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
2 - 9	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
2 - 10	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
3 - 4	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
3 - 5	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
3 - 6	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
3 - 7	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
3 - 8	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
3 - 9	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
3 - 10	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
4 - 5	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
4 - 6	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
4 - 7	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
4 - 8	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
4 - 9	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
4 - 10	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
5 - 6	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
5 - 7	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
5 - 8	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
5 - 9	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
5 - 10	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
6 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.5	0.0
6 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.5	0.0
6 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.5	0.0
6 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 8	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
7 - 9	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
7 - 10	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
8 - 9	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3\right]$	0.5	0.0
8 - 10	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0

Table 10. Linkage analysis of family 6.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(6)}$
1 - 2	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 3	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 3	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0

Continued

5 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
8 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
8 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0

Table 11. Linkage analysis of family 7.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(7)}$
1 - 2	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 3	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 3	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30

Continued

3 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
3 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
3 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
3 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
4 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
4 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
4 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
4 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
4 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
4 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
5 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
5 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
5 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
5 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
5 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
6 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
6 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
6 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
6 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
7 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
7 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
7 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
8 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
8 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30

Table 12. Linkage analysis of family 8.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(8)}$
1 - 2	$Z = \log_{10}\left[2^1 2^1 \theta^1 (1-\theta)^1 \right]$	0.5	0.0
1 - 3	$Z = \log_{10}\left[2^2 2^0 \theta^2 (1-\theta)^0 \right]$	0.5	0.0
1 - 4	$Z = \log_{10}\left[2^2 2^0 \theta^2 (1-\theta)^0 \right]$	0.5	0.0
1 - 5	$Z = \log_{10}\left[2^1 2^1 \theta^1 (1-\theta)^1 \right]$	0.5	0.0
1 - 6	$Z = \log_{10}\left[2^2 2^0 \theta^2 (1-\theta)^0 \right]$	0.5	0.0
1 - 7	$Z = \log_{10}\left[2^1 2^1 \theta^1 (1-\theta)^1 \right]$	0.5	0.0
1 - 8	$Z = \log_{10}\left[2^2 2^0 \theta^2 (1-\theta)^0 \right]$	0.5	0.0
1 - 9	$Z = \log_{10}\left[2^1 2^1 \theta^1 (1-\theta)^1 \right]$	0.5	0.0

Continued

1 - 10	$Z = \log_{10}\left[2^{1}2^{1}\theta^{1}\left(1-\theta\right)^{1} \right]$	0.5	0.0
2 - 3	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
2 - 4	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
2 - 5	$Z = \log_{10}\left[2^{0}2^{2}\theta^{0}\left(1-\theta\right)^{2} \right]$	0.0	0.60
2 - 6	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
2 - 7	$Z = \log_{10}\left[2^{0}2^{2}\theta^{0}\left(1-\theta\right)^{2} \right]$	0.0	0.60
2 - 8	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
2 - 9	$Z = \log_{10}\left[2^{0}2^{2}\theta^{0}\left(1-\theta\right)^{2} \right]$	0.0	0.60
2 - 10	$Z = \log_{10}\left[2^{1}2^{1}\theta^{1}\left(1-\theta\right)^{1} \right]$	0.0	0.0
3 - 4	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
3 - 5	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
3 - 6	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
3 - 7	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
3 - 8	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
3 - 9	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
3 - 10	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
4 - 5	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
4 - 6	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
4 - 7	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
4 - 8	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
4 - 9	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
4 - 10	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
5 - 6	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
5 - 7	$Z = \log_{10}\left[2^{0}2^{2}\theta^{0}\left(1-\theta\right)^{2} \right]$	0.0	0.60
5 - 8	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
5 - 9	$Z = \log_{10}\left[2^{0}2^{2}\theta^{0}\left(1-\theta\right)^{2} \right]$	0.0	0.60
5 - 10	$Z = \log_{10}\left[2^{1}2^{1}\theta^{1}\left(1-\theta\right)^{1} \right]$	0.5	0.0
6 - 7	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
6 - 8	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
6 - 9	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
6 - 10	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
7 - 8	$Z = \log_{10}\left[2^{2}2^{0}\theta^{2}\left(1-\theta\right)^{0} \right]$	0.5	0.0
7 - 9	$Z = \log_{10}\left[2^{0}2^{2}\theta^{0}\left(1-\theta\right)^{2} \right]$	0.0	0.60
7 - 10	$Z = \log_{10}\left[2^{1}2^{1}\theta^{1}\left(1-\theta\right)^{1} \right]$	0.5	0.0

Continued

8 - 9	$Z = \log_{10}\left[2^2 2^0 \theta^2 (1-\theta)^0 \right]$	0.5	0.0
8 - 10	$Z = \log_{10}\left[2^2 2^0 \theta^2 (1-\theta)^0 \right]$	0.5	0.0

Table 13. Linkage analysis of family 9.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(9)}$
1 - 2	$Z = \log_{10}\left[2^1 2^2 \theta^1 (1-\theta)^2 \right]$	0.33	0.07
1 - 3	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
1 - 4	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
1 - 5	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
1 - 6	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
1 - 7	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3 \right]$	0.0	0.90
1 - 8	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
1 - 9	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
1 - 10	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1 \right]$	0.5	0.0
2 - 3	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
2 - 4	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
2 - 5	$Z = \log_{10}\left[2^3 2^2 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
2 - 6	$Z = \log_{10}\left[2^1 2^2 \theta^1 (1-\theta)^2 \right]$	0.33	0.07
2 - 7	$Z = \log_{10}\left[2^1 2^2 \theta^1 (1-\theta)^2 \right]$	0.33	0.07
2 - 8	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
2 - 9	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
2 - 10	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
3 - 4	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
3 - 5	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
3 - 6	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
3 - 7	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
3 - 8	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
3 - 9	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1 \right]$	0.5	0.0
3 - 10	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1 \right]$	0.5	0.0
4 - 5	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
4 - 6	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
4 - 7	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^3 \right]$	0.0	0.9
4 - 8	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
4 - 9	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
4 - 10	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0

Continued

5 - 6	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
5 - 7	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
5 - 8	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
5 - 9	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
5 - 10	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
6 - 7	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
6 - 8	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
6 - 9	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
6 - 10	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
7 - 8	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
7 - 9	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
7 - 10	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
8 - 9	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
8 - 10	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0

Table 14. Linkage analysis of family 10.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(10)}$
1 - 2	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 3	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 3	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30

Continued

3 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
3 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
3 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
3 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
3 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
3 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
4 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
4 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
4 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
4 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
4 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
4 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
5 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
5 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
5 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
5 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
5 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
6 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
6 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
6 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
6 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
7 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
7 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
7 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
8 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
8 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30

Table 15. Linkage analysis of family 11.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(11)}$
1 - 2	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1 \right]$	0.0	0.30
1 - 3	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
1 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
1 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
1 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0
1 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0 \right]$	0.5	0.0

Continued

1 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 3	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0

Continued

7 - 9	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
7 - 10	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
8 - 9	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
8 - 10	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30

Table 16. Linkage analysis of family 12.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(12)}$
1 - 2	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
1 - 3	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
1 - 4	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
1 - 5	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
1 - 6	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
1 - 7	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
1 - 8	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
1 - 9	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
1 - 10	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
2 - 3	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
2 - 4	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
2 - 5	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
2 - 6	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
2 - 7	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
2 - 8	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
2 - 9	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
2 - 10	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
3 - 4	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
3 - 5	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
3 - 6	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
3 - 7	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
3 - 8	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
3 - 9	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}(1-\theta)^{0}\right]$	0.5	0.0
3 - 10	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30
4 - 5	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}(1-\theta)^{1}\right]$	0.0	0.30

Continued

4 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.5	0.0
6 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
7 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
7 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
8 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
8 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30

Table 17. Linkage analysis of family 13.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(13)}$
1 - 2	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 3	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30

Continued

2 - 3	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.5	0.0
6 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
7 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0

Continued

7 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
8 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
8 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30

Table 18. Linkage analysis of family 14.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(14)}$
1 - 2	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 3	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 3	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30

Continued

4 - 5	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}\left(1-\theta\right)^{0}\right]$	0.5	0.0
4 - 6	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
4 - 7	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
4 - 8	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
4 - 9	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
4 - 10	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
5 - 6	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}\left(1-\theta\right)^{0}\right]$	0.5	0.0
5 - 7	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}\left(1-\theta\right)^{0}\right]$	0.5	0.0
5 - 8	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}\left(1-\theta\right)^{0}\right]$	0.5	0.0
5 - 9	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}\left(1-\theta\right)^{0}\right]$	0.5	0.0
5 - 10	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}\left(1-\theta\right)^{0}\right]$	0.5	0.0
6 - 7	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
6 - 8	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
6 - 9	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
6 - 10	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
7 - 8	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
7 - 9	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
7 - 10	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
8 - 9	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
8 - 10	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30

Table 19. Linkage analysis of family 15.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(15)}$
1 - 2	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
1 - 3	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
1 - 4	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}\left(1-\theta\right)^{0}\right]$	0.5	0.0
1 - 5	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}\left(1-\theta\right)^{0}\right]$	0.5	0.0
1 - 6	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}\left(1-\theta\right)^{0}\right]$	0.5	0.0
1 - 7	$Z = \log_{10}\left[2^{1}2^{0}\theta^{1}\left(1-\theta\right)^{0}\right]$	0.5	0.0
1 - 8	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
1 - 9	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30
1 - 10	$Z = \log_{10}\left[2^{0}2^{1}\theta^{0}\left(1-\theta\right)^{1}\right]$	0.0	0.30

Continued

2 - 3	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0

Continued

7 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
8 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
8 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30

Table 20. Linkage analysis of family 16.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(16)}$
1 - 2	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 3	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 3	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0

Continued

4 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
8 - 9	$Z = \log_{10}\left[2^0 2^0 \theta^0 (1-\theta)^1\right]$	0.0	0.30
8 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0

Table 21. Linkage analysis of family 17.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(17)}$
1 - 2	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 3	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
1 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30

Continued

1 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 3	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 4	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 5	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
4 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
5 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 7	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30

Continued

7 - 8	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
7 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
7 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
8 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
8 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30

Table 22. Linkage analysis of family 18.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(18)}$
1 - 2	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 3	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
1 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 3	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 6	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
2 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
2 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
3 - 4	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
3 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0

Continued

3 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 5	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
4 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 6	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
5 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 7	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
6 - 9	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
6 - 10	$Z = \log_{10}\left[2^0 2^1 \theta^0 (1-\theta)^1\right]$	0.0	0.30
7 - 8	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
7 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
8 - 9	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0
8 - 10	$Z = \log_{10}\left[2^1 2^0 \theta^1 (1-\theta)^0\right]$	0.5	0.0

Table 23. Linkage analysis of family 19.

Combination of Markers	LOD	θ_{max}	$Z_{max}^{(19)}$
1 - 2	$Z = \log_{10}\left[2^1 2^2 \theta^1 (1-\theta)^2\right]$	0.33	0.07
1 - 3	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0
1 - 4	$Z = \log_{10}\left[2^1 2^2 \theta^1 (1-\theta)^2\right]$	0.33	0.07
1 - 5	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0\right]$	0.5	0.0
1 - 6	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0
1 - 7	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0
1 - 8	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0

Continued

1 - 9	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3 \right]$	0.0	0.90
1 - 10	$Z = \log_{10}\left[2^0 2^3 \theta^0 (1-\theta)^3 \right]$	0.0	0.90
2 - 3	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1 \right]$	0.5	0.0
2 - 4	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1 \right]$	0.5	0.0
2 - 5	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
2 - 6	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
2 - 7	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
2 - 8	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
2 - 9	$Z = \log_{10}\left[2^1 2^2 \theta^1 (1-\theta)^2 \right]$	0.33	0.07
2 - 10	$Z = \log_{10}\left[2^1 2^2 \theta^1 (1-\theta)^2 \right]$	0.33	0.07
3 - 4	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1 \right]$	0.5	0.0
3 - 5	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
3 - 6	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
3 - 7	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
3 - 8	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
3 - 9	$Z = \log_{10}\left[2^1 2^2 \theta^1 (1-\theta)^2 \right]$	0.33	0.07
3 - 10	$Z = \log_{10}\left[2^1 2^2 \theta^1 (1-\theta)^2 \right]$	0.33	0.07
4 - 5	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
4 - 6	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1 \right]$	0.5	0.0
4 - 7	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1 \right]$	0.5	0.0
4 - 8	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1 \right]$	0.5	0.0
4 - 9	$Z = \log_{10}\left[2^1 2^2 \theta^1 (1-\theta)^2 \right]$	0.33	0.07
4 - 10	$Z = \log_{10}\left[2^1 2^2 \theta^1 (1-\theta)^2 \right]$	0.33	0.07
5 - 6	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
5 - 7	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
5 - 8	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
5 - 9	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
5 - 10	$Z = \log_{10}\left[2^3 2^0 \theta^3 (1-\theta)^0 \right]$	0.5	0.0
6 - 7	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1 \right]$	0.5	0.0
6 - 8	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1 \right]$	0.5	0.0
6 - 9	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1 \right]$	0.5	0.0

Continued

6 - 10	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0
7 - 8	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0
7 - 9	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0
7 - 10	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0
8 - 9	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0
8 - 10	$Z = \log_{10}\left[2^2 2^1 \theta^2 (1-\theta)^1\right]$	0.5	0.0