

Web-based Supporting Materials for “Bayesian analysis of multi-type recurrent events and dependent termination with nonparametric covariate function” by Li-An Lin, Sheng Luo, Bingshu E. Chen, and Barry R. Davis

WinBUGS program to fit the joint model

```

model {
  for (i in 1:I) {
    # nonparametric covariate function for type 1 recurrent events
    fz1[i] <- zs[i,1]*u1[1] + zs[i,2]*u1[2] + zs[i,3]*u1[3]+ zs[i,4]*u1[4]
      + zs[i,5]*u1[5]+ zs[i,6]*u1[6]+ zs[i,7]*u1[7]+ zs[i,8]*u1[8]
      + zs[i,9]*u1[9]+ zs[i,10]*u1[10]
    #covariate effect for type 1 recurrent events
    covr1[i] <- x1[i] * beta1 + b[i,1] + fz1[i]
    # nonparametric covariate function for type 2 recurrent events
    fz2[i] <- zs[i,1]*u2[1] + zs[i,2]*u2[2] + zs[i,3]*u2[3]+ zs[i,4]*u2[4]
      + zs[i,5]*u2[5]+ zs[i,6]*u2[6]+ zs[i,7]*u2[7]+ zs[i,8]*u2[8]
      + zs[i,9]*u2[9]+ zs[i,10]*u2[10]
    #covariate effect for type 2 recurrent events
    covr2[i] <- x2[i] * beta2 + b[i,2] + fz2[i]
    #covariate effect for terminal event
    covd[i] <- z1[i] * eta0 + x1[i] * eta1 + x2[i] * eta2 + delta1*b[i,1]
      +delta2*b[i,2]

#####
# construct the likelihood function
#####
    for (j in 1:g[1]) {
      mud[i,j] <- (time.matrix.d[i, j + 1] - time.matrix.d[i, j]) * exp(covd[i])*lambda0[j]
      dN.d[i, j] ~ dpois(mud[i,j])
    }
    for(j in 1:g[2]){
      mur1[i,j] <- (time.matrix.r1[i, j + 1] - time.matrix.r1[i, j])*exp(covr1[i])*r01[j]
      dN.r1[i, j] ~ dpois(mur1[i,j])
    }
    for(j in 1:g[3]){
      mur2[i,j] <- (time.matrix.r2[i, j + 1] - time.matrix.r2[i, j])*exp(covr2[i])*r02[j]
      dN.r2[i, j] ~ dpois(mur2[i,j])
    }
  }

#####
# Impose priors for all parameters

```

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#####

#prior for covariance matrix, use Cholesky decomposition
for ( i in 1:I) {
  xb1[i] ~ dnorm(0,1)
  xb2[i] ~ dnorm(0,1)
  b[i,1] <- w[1]*xb1[i]
  b[i,2] <- w[2]*xb1[i]+w[3]*xb2[i]
}
w[1] ~ dunif(-5,5)
w[2] ~ dunif(0,10)
w[3] ~ dunif(-10,10)

#prior for Bayesian B-spline
u1[1] ~ dunif(-5,5)
u2[1] ~ dunif(-5,5)
for(i in 2:10){
  u1[i] ~ dnorm(u1[i-1], tau.u1)
  u2[i] ~ dnorm(u2[i-1], tau.u2)
}

#prior for baseline hazard
for(j in 1:g[1]){
  r01[j] ~ dgamma(0.01, 0.01)
}
for(j in 1:g[2]){
  r02[j] ~ dgamma(0.01, 0.01)
}
for (j in 1:g[3]) {
  lambda0[j] ~ dgamma(0.01, 0.01)
}

#prior for regression coefficients
eta0 ~ dnorm(0, 0.01)
eta1 ~ dnorm(0, 0.01)
eta2 ~ dnorm(0, 0.01)
beta1 ~ dnorm(0, 0.01)
beta2 ~ dnorm(0, 0.01)
delta1 ~ dnorm(0.0,0.01)
delta2 ~ dnorm(0.0,0.01)

#hyper prior for B-spline
tau.u1 ~ dgamma(0.01,0.01)
tau.u2 ~ dgamma(0.01,0.01)

#construct the variance-covariance matrix
sigma.u1 <- 1/sqrt(tau.u1)
sigma.u2 <- 1/sqrt(tau.u2)
sigma.b[1] <- w[1]
sigma.b[2] <- sqrt(w[2]*w[2]+w[3]*w[3])
rho <- w[2]/sqrt(w[2]*w[2]+w[3]*w[3])
}

```

Table 1: Parameter estimation results of the risk of recurrent **CHD** events from the joint, reduced, and parametric models. PM: posterior mean.

	Joint Model				Reduced Model				Parametric Model			
	PM	SD	95% CI		PM	SD	95% CI		PM	SD	95% CI	
age									0.078	0.007	0.065	0.091
llt	0.128	0.088	-0.044	0.302	0.141	0.080	-0.019	0.297	0.130	0.090	-0.044	0.308
att=1	-0.018	0.127	-0.258	0.240	0.012	0.111	-0.204	0.234	-0.013	0.123	-0.252	0.237
att=2	0.122	0.139	-0.147	0.392	0.125	0.123	-0.123	0.372	0.124	0.140	-0.145	0.402
att=3	0.052	0.142	-0.231	0.326	0.076	0.125	-0.172	0.322	0.052	0.144	-0.233	0.330
gender	-0.599	0.108	-0.811	-0.387	-0.486	0.097	-0.684	-0.302	-0.613	0.107	-0.821	-0.410
race	0.129	0.099	-0.068	0.323	0.024	0.092	-0.153	0.203	0.116	0.102	-0.086	0.316
bmi	-0.006	0.008	-0.022	0.011	0.001	0.008	-0.015	0.017	-0.004	0.009	-0.021	0.013
sbp	0.017	0.004	0.010	0.025	0.013	0.003	0.007	0.020	0.017	0.004	0.010	0.024
dbp	-0.017	0.005	-0.027	-0.007	-0.016	0.005	-0.025	-0.006	-0.016	0.005	-0.026	-0.006
diabetes	-0.543	0.099	-0.733	-0.341	-0.411	0.088	-0.578	-0.236	-0.562	0.103	-0.761	-0.358
lchd	-0.662	0.125	-0.898	-0.420	-0.611	0.108	-0.825	-0.401	-0.657	0.126	-0.913	-0.404
hdl	-0.007	0.004	-0.015	0.000	-0.007	0.004	-0.014	0.000	-0.007	0.004	-0.015	0.000
ldl	0.004	0.002	0.000	0.009	0.005	0.002	0.001	0.009	0.005	0.002	0.000	0.009
cursmk=1	-0.817	0.120	-1.056	-0.578	-0.621	0.108	-0.833	-0.407	-0.822	0.125	-1.065	-0.568
cursmk=2	-0.825	0.126	-1.072	-0.573	-0.567	0.112	-0.783	-0.338	-0.861	0.131	-1.112	-0.603
aspirin	-0.321	0.098	-0.505	-0.128	-0.274	0.085	-0.443	-0.103	-0.328	0.100	-0.524	-0.133
blmeds	-0.556	0.185	-0.913	-0.199	-0.503	0.160	-0.840	-0.208	-0.555	0.180	-0.917	-0.202

Table 2: Parameter estimation results of the risk of recurrent **strokes** events from the joint, reduced, and parametric models. PM: posterior mean.

	Joint Model				Reduced Model				Parametric Model			
	PM	SD	95% CI		PM	SD	95% CI		PM	SD	95% CI	
age									0.088	0.008	0.072	0.104
llt	0.101	0.110	-0.112	0.319	0.105	0.110	-0.109	0.318	0.094	0.111	-0.121	0.315
att=1	-0.317	0.149	-0.613	-0.032	-0.295	0.151	-0.598	-0.005	-0.313	0.142	-0.591	-0.036
att=2	-0.356	0.173	-0.708	-0.028	-0.366	0.174	-0.721	-0.030	-0.349	0.168	-0.677	-0.025
att=3	-0.129	0.166	-0.468	0.193	-0.123	0.167	-0.457	0.201	-0.130	0.160	-0.437	0.185
gender	-0.215	0.129	-0.468	0.029	-0.133	0.130	-0.381	0.125	-0.230	0.126	-0.482	0.009
race	0.600	0.120	0.364	0.830	0.532	0.120	0.298	0.762	0.582	0.120	0.350	0.819
bmi	-0.013	0.011	-0.034	0.009	-0.010	0.011	-0.031	0.012	-0.010	0.011	-0.032	0.010
sbp	0.019	0.005	0.010	0.028	0.017	0.005	0.008	0.026	0.018	0.005	0.009	0.027
dbp	-0.013	0.006	-0.025	-0.001	-0.010	0.006	-0.023	0.003	-0.011	0.006	-0.023	0.001
diabetes	-0.529	0.123	-0.771	-0.280	-0.438	0.122	-0.674	-0.201	-0.551	0.119	-0.778	-0.320
lchd	-0.259	0.158	-0.562	0.056	-0.190	0.162	-0.519	0.127	-0.260	0.162	-0.574	0.059
hdl	-0.008	0.004	-0.017	0.001	-0.007	0.005	-0.016	0.002	-0.007	0.005	-0.017	0.001
ldl	0.001	0.003	-0.004	0.006	0.001	0.003	-0.004	0.007	0.001	0.003	-0.004	0.007
cursmk=1	-0.532	0.154	-0.833	-0.220	-0.339	0.159	-0.657	-0.028	-0.556	0.156	-0.863	-0.245
cursmk=2	-0.596	0.160	-0.910	-0.276	-0.385	0.165	-0.715	-0.063	-0.649	0.158	-0.954	-0.337
aspirin	-0.456	0.122	-0.698	-0.222	-0.430	0.123	-0.678	-0.195	-0.463	0.119	-0.693	-0.230
blmeds	-0.414	0.222	-0.854	0.016	-0.422	0.219	-0.870	-0.004	-0.413	0.215	-0.841	-0.007

Table 3: Parameter estimation results of the risk of recurrent **heart failure** events from the joint, reduced, and parametric models. PM: posterior mean.

	Joint Model				Reduced Model				Parametric Model			
	PM	SD	95% CI		PM	SD	95% CI		PM	SD	95% CI	
age									0.117	0.008	0.101	0.134
llt	-0.048	0.113	-0.267	0.179	-0.046	0.119	-0.284	0.189	-0.045	0.115	-0.264	0.174
att=1	-0.670	0.153	-0.966	-0.364	-0.686	0.164	-1.007	-0.362	-0.663	0.149	-0.955	-0.376
att=2	-0.130	0.161	-0.447	0.185	-0.138	0.170	-0.477	0.188	-0.129	0.164	-0.443	0.194
att=3	-0.564	0.176	-0.913	-0.223	-0.586	0.186	-0.952	-0.214	-0.562	0.175	-0.908	-0.220
gender	-0.213	0.135	-0.474	0.052	-0.171	0.140	-0.455	0.106	-0.219	0.140	-0.506	0.046
race	0.435	0.124	0.186	0.675	0.344	0.129	0.094	0.590	0.424	0.128	0.170	0.665
bmi	0.027	0.011	0.007	0.048	0.038	0.011	0.016	0.060	0.031	0.011	0.009	0.051
sbp	0.020	0.005	0.011	0.030	0.018	0.005	0.009	0.028	0.019	0.005	0.010	0.029
dbp	-0.022	0.006	-0.034	-0.009	-0.022	0.007	-0.035	-0.009	-0.020	0.006	-0.033	-0.007
diabetes	-0.771	0.120	-0.999	-0.541	-0.699	0.125	-0.939	-0.458	-0.772	0.128	-1.022	-0.518
lchd	-0.590	0.159	-0.894	-0.281	-0.617	0.160	-0.928	-0.309	-0.586	0.162	-0.902	-0.271
hdl	-0.021	0.005	-0.030	-0.011	-0.022	0.005	-0.033	-0.012	-0.020	0.005	-0.030	-0.010
ldl	0.000	0.003	-0.006	0.005	0.000	0.003	-0.005	0.006	0.000	0.003	-0.006	0.005
cursmk=1	-0.779	0.159	-1.094	-0.474	-0.657	0.164	-0.972	-0.334	-0.809	0.157	-1.102	-0.491
cursmk=2	-1.028	0.167	-1.353	-0.700	-0.868	0.172	-1.198	-0.532	-1.071	0.166	-1.401	-0.747
aspirin	-0.373	0.126	-0.611	-0.120	-0.360	0.129	-0.612	-0.099	-0.366	0.126	-0.619	-0.117
blmeds	-0.724	0.237	-1.204	-0.277	-0.778	0.250	-1.270	-0.283	-0.710	0.237	-1.178	-0.245

Table 4: Parameter estimation results of the hazard of **all-cause mortality** from the joint, reduced, and parametric models. PM: posterior mean.

	Joint Model				Reduced Model				Parametric Model			
	PM	SD	95% CI		PM	SD	95% CI		PM	SD	95% CI	
age	0.155	0.011	0.134	0.177	0.079	0.004	0.071	0.087	0.159	0.012	0.138	0.182
llt	0.025	0.119	-0.205	0.265	0.035	0.059	-0.084	0.153	0.020	0.118	-0.208	0.254
att=1	-0.121	0.170	-0.461	0.210	-0.005	0.082	-0.165	0.155	-0.114	0.158	-0.422	0.194
att=2	-0.006	0.186	-0.359	0.360	-0.006	0.089	-0.174	0.172	-0.018	0.179	-0.361	0.333
att=3	0.012	0.191	-0.361	0.384	0.075	0.088	-0.103	0.247	0.003	0.184	-0.359	0.359
gender	-0.726	0.146	-1.013	-0.444	-0.295	0.068	-0.432	-0.163	-0.728	0.146	-1.012	-0.440
race	0.522	0.135	0.255	0.791	0.211	0.063	0.083	0.333	0.489	0.137	0.236	0.766
bmi	-0.017	0.012	-0.040	0.006	-0.012	0.006	-0.024	0.000	-0.013	0.012	-0.037	0.011
sbp	0.023	0.005	0.013	0.034	0.011	0.002	0.006	0.015	0.023	0.005	0.012	0.033
dbp	-0.014	0.007	-0.027	0.000	-0.005	0.003	-0.011	0.002	-0.011	0.007	-0.025	0.002
diabetes	-0.822	0.141	-1.103	-0.543	-0.381	0.064	-0.507	-0.253	-0.817	0.138	-1.091	-0.547
lchd	-0.451	0.178	-0.796	-0.108	-0.154	0.084	-0.319	0.011	-0.437	0.177	-0.783	-0.084
hdl	-0.005	0.005	-0.015	0.004	-0.004	0.002	-0.008	0.001	-0.004	0.005	-0.014	0.005
ldl	0.000	0.003	-0.006	0.006	0.000	0.001	-0.003	0.003	0.000	0.003	-0.006	0.006
cursmk=1	-1.343	0.169	-1.688	-1.026	-0.632	0.076	-0.784	-0.486	-1.338	0.176	-1.683	-1.001
cursmk=2	-1.822	0.186	-2.191	-1.459	-0.864	0.082	-1.026	-0.709	-1.832	0.194	-2.227	-1.465
aspirin	-0.377	0.137	-0.644	-0.104	-0.130	0.064	-0.257	-0.008	-0.370	0.135	-0.636	-0.120
blmeds	-0.510	0.231	-0.961	-0.055	-0.281	0.109	-0.495	-0.068	-0.501	0.223	-0.948	-0.077
σ_1	2.117	0.076	1.969	2.269	1.400	0.065	1.276	1.528	2.117	0.078	1.972	2.277
σ_2	2.036	0.096	1.852	2.229	1.667	0.103	1.473	1.869	2.033	0.099	1.834	2.228
σ_3	2.456	0.092	2.278	2.643	2.286	0.094	2.112	2.475	2.467	0.089	2.296	2.644
ρ_{21}	0.864	0.034	0.792	0.923	0.576	0.074	0.424	0.708	0.875	0.035	0.797	0.937
ρ_{31}	0.921	0.018	0.881	0.952	0.986	0.014	0.949	1.000	0.929	0.018	0.893	0.961
ρ_{32}	0.708	0.041	0.625	0.786	0.547	0.062	0.422	0.665	0.712	0.041	0.630	0.788
δ_1	1.671	0.420	0.943	2.680					0.812	0.667	0.748	2.942
δ_2	0.364	0.226	-0.176	0.754					0.749	0.790	-0.348	1.656
δ_3	-0.135	0.218	-0.661	0.235					0.102	0.654	-1.023	1.322

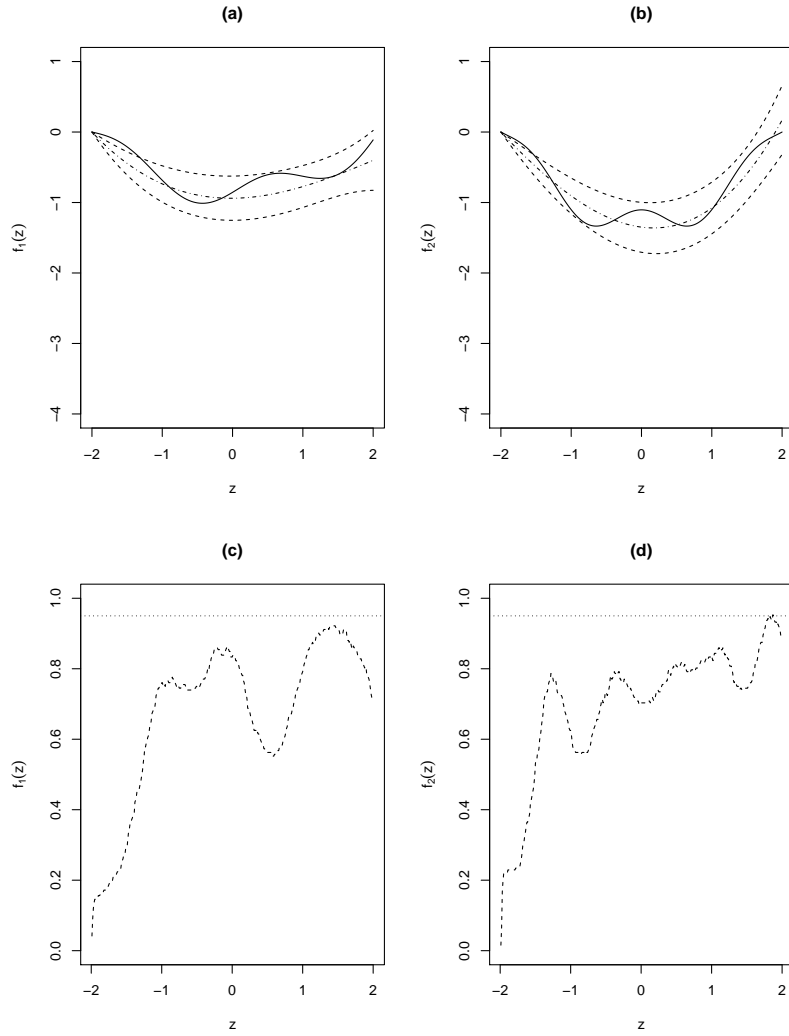


Figure 1: The polynomial regression model’s estimates of nonparametric covariate functions in simulation setting I. Estimates of $f_1(Z)$ (panel a) and $f_2(Z)$ (panel b). True functions, solid; estimated functions, dotdash; 95% pointwise credible intervals, dashed. Coverage probabilities of the 95% pointwise credible intervals for $f_1(Z)$ (panel c) and $f_2(Z)$ (panel d) with a reference line (dotted) at 0.95.

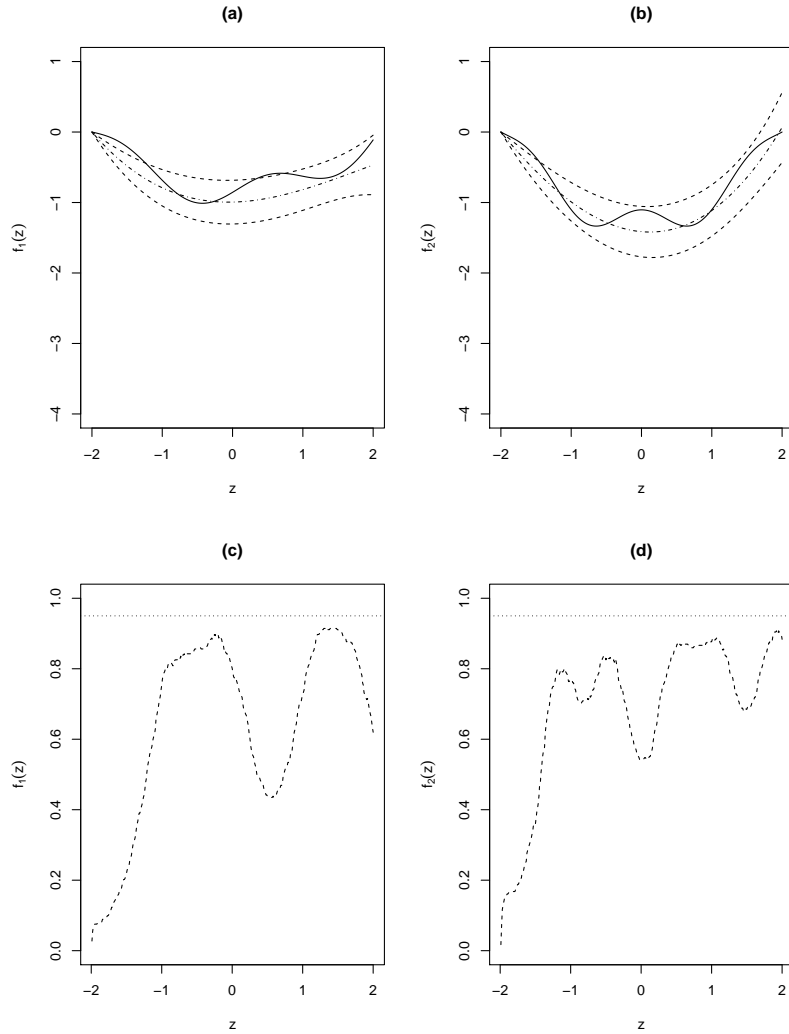


Figure 2: The polynomial regression model’s estimates of nonparametric covariate functions in simulation setting II. Estimates of $f_1(Z)$ (panel a) and $f_2(Z)$ (panel b). True functions, solid; estimated functions, dotdash; 95% pointwise credible intervals, dashed. Coverage probabilities of the 95% pointwise credible intervals for $f_1(Z)$ (panel c) and $f_2(Z)$ (panel d) with a reference line (dotted) at 0.95.