BIOS 7721 – Joint Modeling of Longitudinal and Survival Data
Syllabus and Schedule of Activities, Spring 2021
One credit

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Course Description: BIOS 7721 – This course provides an introduction to joint modeling of longitudinal and survival data and its application in health research. Topics include Linear Mixed Effects Models, Survival Analysis, Random Effects Joint Model, and possibly Dynamic Prediction. (1 credit) Prerequisite: BIOS 6643 or consent of instructor. Offered spring semester, variable years.

Prerequisites: BIOS 6643 Longitudinal Data or consent of instructor.

Course objectives: At the completion of BIOS 7721 students will be able to:

1. Identify whether a research question requires joint modeling.
2. Understand and be able to discuss standard methods for the modeling of longitudinal data using Linear Mixed Effects Models, and survival data using Relative Risk Models.
3. Understand and be able to discuss the assumptions and estimation of a Standard Joint Model.
4. Carry out, interpret, and report analyses of a Standard Joint Model using R statistical software.
5. Understand and be able to discuss missing data mechanisms, nonrandom dropout and censoring.
6. Understand and discuss some issues, controversies, and extensions in this area.

Competencies mapped to this course for assessment
This course addresses the following competencies, and is used for assessing achievement:

PHD-BIOS 9	Carry out advanced statistical modeling using a range of statistical theory, methods and computation.
PHD-BIOS 10	Demonstrate advanced collaborative biostatistical skills, including formulating testable study aims, identifying, designing and evaluating statistical analyses appropriate for study aims, reading and synthesizing biostatistical literature relevant to study analyses, and suggesting new methods when existing approaches are inadequate.
MS-BIOS 4	Carry out valid and efficient modeling, estimation, model checking and inference using standard statistical methods and software.

Integration of this Course with other Biostatistics courses:
This course builds on the theory and methods for analysis of clustered and longitudinal data covered in BIOS 6643 Longitudinal Data, by using knowledge about the estimation and implementation of linear mixed effects models in a joint model framework. It also has connections with BIOS 7713 Analysis of Missing Data, by describing mechanisms of missingness, and BIOS 6646 Survival Analysis, which also covers Cox proportional hazards regression and time-dependent covariates.

Textbook: Rizopoulos, D. (2012). *Joint models for longitudinal and time-to-event data: With applications in R*. CRC press. (not required to purchase)

Software: R, an open-source software that is free and can be downloaded.

Course Requirements: Assessment will be based on

a. Homework (45%)
b. Class participation (25%)
c. Final project (30%)

Homework Assignments:
In order to receive credit, homework assignments should be neat, well organized, and typed whenever possible. Raw computer output from a statistical package by itself is not acceptable. Numerical output should be incorporated into text or tables, and plots should be electronically or manually integrated into the pages to be turned in. Plots should be labeled, including axis labels. Late homework is not accepted without prior permission from the instructor.

Students may be expected to extend ideas from class on assignments. Problems will not be identical to examples covered in lectures, so students are encouraged to consult resources other than the lecture notes. Students may work together on homework assignments; however, the assignment handed in must represent the student's own work and may not be identical for multiple students. Students must follow the Honor Code below.

Class Participation:
Students will be required to attend and participate in class discussions. Class participation will be assessed based on weekly quizzes, posting on course discussion boards (questions, answers, interesting observations, etc.), asking questions during class, etc.

Final Project:
The final project will be a choice of (1) reading and presenting on a paper related to joint modeling or (2) conducting a simulation study. For the paper option, students can work in groups of two and will be expected to read an approved paper, prepare and give an in-class presentation, and submit a 2-3 page summary of the key findings. For the simulation option, students will work alone and will be required to submit a 1-2 page summary of their simulation results and key findings (no in-class presentation will be required).

FINAL GRADES: The following grading scale will be used for final grades:

A	94.00-100	B-	80.00-83.99	D+	67.00-69.99
A-	90.00-93.99	C+	77.00-79.99	D	64.00-66.99
B+	87.00-89.99	C	74.00-76.99	D-	60.00-63.99
B	84.00-86.99	C-	70.00-73.99	F	0 – 59.99

Students in the Biostatistics MS or PhD programs must earn a B- or better in this elective course.

Course Policies:

Academic Conduct Policy
All students are expected to abide the Honor Code of the Colorado School of Public Health. Unless otherwise instructed, all of your work in this course should represent completely independent work. Students are expected to familiarize themselves with the Student Honor Code that can be found at
https://www.ucdenver.edu/docs/librariesprovider151/default-document-library/coloradosph-honor-code.pdf?sfvrsn=5d211eb9_4
or the Education – Calendar and Policies section of the ColoradoSPH website. Any student found to have committed acts of misconduct (including, but not limited to cheating, plagiarism, misconduct of research, breach of confidentiality, or illegal or unlawful acts) will be subject to the procedures outlined in the ColoradoSPH Honor Code.

Accommodations for Disabilities: Virtual and In-Class
University of Colorado Anschutz is committed to providing equitable access to learning opportunities to students with documented disabilities (e.g. mental health, attentional, learning, chronic health, sensory, or physical). To ensure access to this class, and program, please contact Sherry Holden (sherry.holden@cuanschutz.edu) for disability services to engage in a confidential conversation about the process for requesting reasonable accommodations in the classroom and clinical settings.

Accommodations are not provided retroactively Students are encouraged to register with Disability Resources and Services as soon as they begin their program. The Colorado School of Public Health encourages students to access all resources available through Disability Resources and Services for consistent support and access to their programs. More information can be found online at:
http://www.ucdenver.edu/student-services/resources/disability-resources-services/CU%20ANSCHUTZ%20MEDICAL%20CAMPUS/CU%20Anschutz%20Disability%20Resources%20Contact%20Form/Pages/form.aspx.

Mental Health Services
https://www.ucdenver.edu/life/services/student-health/mental-wellness/Pages/default.aspx

Spring 2021 Course Outline

Module	Outline	Homework	Suggested Readings
1 (Day 1)	**Introduction to Joint Modeling** • Introduction, Syllabus, Overview, Examples	HW 1	Riz, CH 1
2 (Day 2)	**Longitudinal Data Analysis** • Linear Mixed Effects Models (Notation, Estimation, Implementation in Software) • Missing data in longitudinal studies (Missing data mechanisms)	HW 1	Riz, CH 2
3 (Day 3)	**Survival Analysis** • Time-to-event data (Survival time, Censoring) • Survival analysis (Notation, Basic functions, Estimators, Relative Risk model, Estimation)	HW 1	Riz, CH 3
(Day 4)	• Time-dependent covariates (Internal vs. External, Cox model, Estimation) • Two-stage models	HW 2	Riz, CH 3
4 (Day 5)	**The Basic Joint Model** • Survival submodel (Notation) • Longitudinal submodel (Notation) • Basic random effects joint model (Joint likelihood, Assumptions) • Estimation (Maximum Likelihood) • Inference	HW 3	Riz, CH 4
5 (Day 6)	**Joint Models in R** • Demonstrate software (Fit model, Interpret results)	HW 3	Riz, CH 4
6 (Day 7)	**Extensions to the Basic Joint Model** • Other parameterizations	HW 3	Riz, CH 5
7 (Day 8)	**Missing Data** • Nonrandom dropout and censoring (Missing data mechanisms)	HW 3	Riz, CH 4
8 (Day 9)	**Introduction to Dynamic Prediction** • Survival prediction • Dynamic prediction Assessing predictive performance		Riz, CH 7
9 (Day 10)	**Extensions of Joint Models** • Survival submodel (competing risks, recurrent events, nonproportional hazards, AFT models) • Longitudinal submodel (discrete outcomes, multiple biomarkers)	Presentations	