Time-to-event analyses in sports injury research

Laurent Malisoux

Sports Medicine Research Laboratory, Department of Population Health, Luxembourg Institute of Health, Luxembourg, Laurent.Malisoux@lih.lu

Abstract. Injury prevention is an important goal for clinicians, researchers, athletes, and the active population as any effective preventive measure might contribute not only to continuing competitive participation but also to maintaining an active, healthy lifestyle. According to the sequence of sports injury prevention suggested by van Mechelen, the first steps of any preventive approach consist in 1) assessing the extent of the sports injury problem, and 2) describing the aetiology and mechanism of injury. So far, the majority of studies in sports injury prevention have focused on the identification of risk factors and the understanding of the synergy between them. Unfortunately, the aetiology of injury is still insufficiently understood. The main reason is that the mechanisms underlying most sports injuries are specific, complex, multifactorial, recursive and dynamic. Therefore, large-cohort studies with robust study designs and advanced statistical approaches are needed. The aims of this talk are to explain why time-to-event analysis appears to be well suited to the specific needs of sports injury researchers, and to address advanced statistical methods that should be considered when investigating injury aetiology. Survival analysis was originally developed to be applied in settings where there is only a single type of mortality-related event. Today, the models are used with other types of events, including sports injuries. Importantly, the latter event of interest can only occur when athletes are practising sport. As a consequence, the time scale should not be calendar time but an exposure-related scale such as kilometres, hours of training, throws or strides, to name but a few. When compared with logistic regression, time-to-event analysis offers that possibility to adjust for the fact that time at risk can vary greatly between athletes.

Another advantage of time-to-event analysis is that it allows taking into account censoring, which is athlete withdrawal before injury occurrence. Reasons of censoring might be lack of motivation, pregnancy, death, or simply the end of the data collection period. Censoring is not similar to exclusion since censored participants are included in the analysis whereas the data from those excluded are omitted. Participant exclusion leads to loss of information and is a potential source of bias given that excluded participants actually contribute to generating information with a certain time at risk without sustaining injury while being in the study.

One critical feature of prospective sports injury data is that exposures such as training load, strength or equipment change over time (time-varying exposures). Sports scientists usually assume that excessive progression in training load can lead to injury. The main exposure of interest should therefore be a time-varying variable such as changes in training load. As a matter of fact, researchers can examine the association between exposure levels

and injury risk, as well as between changes in exposure and injury risk depending on their research question. Other variables such as strength, body mass and flexibility will modify the training load which an athlete can tolerate before sustaining an injury. Thus, these variables should be included as time-varying effect-measure modifiers and/or time-varying confounders.

The injury-related data could be either dichotomised (e.g. yes or no) or categorised in different states (e.g. severe, moderate or no injury) or types (e.g. according to the anatomical location). First, the research question might focus on changes in injury state over time. Including the concept of time-varying outcome, time-to-event models are well suited to dealing with multiple-state outcomes, and therefore, to investigating risk factors and mechanisms associated with a transition between injury states. Second, the outcome could transit to a "no injury" state prior to progressing toward a new "moderate injury". In other words, during a specific period, an athlete might sustain more than 1 injury. Analysing subsequent injuries is complex, as many types of connections between them exist. Joint efforts from sports scientists and statisticians are needed to come up with solutions to deal with subsequent sports injury data.

Athletes are exposed to a simultaneous risk of several types of injuries, which are considered competing given that an athlete can only sustain one type of injury at a given point in time. Although some extra efforts with respect to data preparation and programming are required, methods to analyse such models have been developed.

In conclusion, this talk will show that time-to-event modelling is the method of choice for sports injury researchers as it allows sufficient flexibility for researchers to take into account censoring, deal with time-varying exposures, consider time-varying injuries and subsequent injuries, as well as to include many types of injuries using a competing-risk approach. To increase knowledge about injury aetiology, sports injury researchers should collaborate with statisticians to apply meaningful and appropriate time-to-event models to their prospective data.

Keywords. Time-varying exposure, Time-varying outcome, Subsequent injuries, Competing risk