

Age at menarche and its relationship to body mass index among adolescent girls in Chile: a joint modeling approach

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Puberty is the period between childhood and adulthood when sexual development takes place. Menarche marks the beginning of the female reproductive capacity and is a significant developmental milestone for girls during this period. It typically occurs 2-2.5 years after puberty starts. Studies show that the average age at menarche has decreased from 17 years in 1840 to about 12 years in 2000 in most developed nations. The onset of menarche is influenced by both hereditary and environmental factors, with higher BMI being associated with earlier onset.

In this study, we analyze data from the Growth and Obesity Chilean Cohort Study to model the age at menarche based on BMI and other factors, modeling these variables jointly using a shared random-effects approach. We implemented a mixed model for the longitudinal marker, BMI, and a polynomial regression to model the age at menarche, including characteristics of the mixed model as covariates. Further, as an alternative approach, we categorize the age at menarche into three groups: early age menarche (<12 years), normal age menarche (between 12 and 14 years), and late age menarche (>14 years), and use a categorical data model.

Estimation of this kind of model may be challenging. Firstly, we propose to use a two-stage approach to obtain the maximum likelihood estimates based on linearization or approximation methods. As an alternative, we also apply the Stochastic Approximation version of the EM (SAEM) to estimate jointly the parameters of these models. With both approaches, we observe that the shared parameters seem to be significant which confirms the link between the BMI and the age at menarche.

Keywords: Joint model; Mixed effects models; SAEM algorithm