ANALYZING KINEMATICS VARIABLES: A STRUCTURAL EQUATION MODEL APPLICATION FOR THE ASSESSMENT OF SKATING IN DEVELOPMENTAL AND ELITE ICE HOCKEY PLAYERS

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The purpose of this presentation is to describe an approach in which bivariate correlation followed by exploratory factor analysis and structural equation modelling was used to make sense of kinematic parameters for the purpose of predicting time to skate six meters. Two studies were completed in order to predict on-ice acceleration in both developmental and elite ice hockey players based on the kinematic variables from 3D biomechanical analyses of the skating technique. Through the creation of latent variables, the approach generated valuable information for the coach and the player about the way in which body movements work together to predict performance.

KEY WORDS: exploratory factor analysis, on-ice acceleration, forward skating technique, latent variables.

INTRODUCTION: Traditionally, statistical analyses in "applied sport biomechanics" have focused on providing descriptive statistics, which summarize the dependent measures, followed by estimates of correlation and regression to demonstrate the predictive association between independent measures and selected dependent variables. Although these approaches are effective exploratory techniques, used often in the statistical evaluation of biomechanical data, they may not provide an understanding of the interaction between variables and may be inappropriate in designs based on repeated sampling.

In biomechanics the variable types that are used to describe the movements of a measurable performance include: 1) categorical variables, 2) manifest variables, or 3) derived variables. Categorical variables are the independent, organizational variables, which describe the demographic characteristics of the sample (e.g. gender, age group, activity group). Manifest variables contain actual observations from direct measurements. Derived variables contain the result of computations applied to the manifest variables. Manifest and derived variables are continuous random variables, which may take on the role of the dependent variable or belong to the set of independent variables, especially when using a linear equation to describe the movement or performance. Although the manifest and derived variables are effective exploratory techniques for within group cross-sectional studies, they may not provide an understanding of the interaction between variables that describe the event across repeated sampling. An additional variable type is "the latent variable. Latent variables are constructed from a correlation matrix computed for the set of primary variables and thus describe the structure of the grouping of primary variables, not the statistical association between the primary variables.

Exploratory factor analysis produces latent variables that represent groups of primary variables (manifest variables, derived variables, or a combination of manifest and derived variables) and can be used to explore the association between variables. Exploratory factor analysis (FA) allows the researcher to extend prediction beyond the univariate statistical model to a structural equation in which dependent variables are processed against latent factors (Tabachnick & Fidell, 1996).

Our first foray into the application of structural equation modelling with latent variable predictors was in the use of factor analysis to explain the kinematic analysis of variables observed from a 70 meter ski jumping event. The purpose of the study was to examine the use of factor analysis to reduce a large variable set, and minimize inter-subject variance in a structural equation model of ski jumping mechanics. The study was based on the biomechanical analyses of 40 males competing in a 1996 Nordic Combined World Cup. Exploratory factor analysis was first used to evaluate variables at three different points during the mid-flight phases, and then to produce structures that were used as predictors in a confirmatory

backward regression. The results of the approach demonstrated the importance of the angle between the leg and the direction of flight, the ski and the direction of flight, and the angle between the ski and the trunk. The utility of the FA as a data reduction strategy was essential to producing variable sets which minimized the influence of inter-subject variability.
Success in ice hockey depends on an individual's ability to accelerate from a standing start or from a change in direction (Marino, 1983). Researchers have shown that optimal acceleration in skating is a function of high stride rate, low angle of forward lean at touchdown, small single support time, small toe-to-hip distance at touchdown, combined with player height & weight, and leg length (Marino & Dillman, 1976; Pagé, 1976; Marino, 1983). Previous research to determine those factors which provided the greatest contribution to on-ice acceleration has been limited to 2D biomechanical analyses of skating technique and the application of traditional descriptive and regression analyses where data collected over multiple strides has been collapsed into single mean score.

METHOD: Two studies were completed in order to predict on-ice acceleration in both developmental and elite ice hockey players based on the kinematic variables from 3D biomechanical analyses of the skating technique. The two studies involved 37 hockey players participating in a 1999 Prospects Camp and 30 male development-age players categorized by level of play. The players performed two maximal, on-ice accelerations over a distance of 20 meters, while being recorded by two digital cameras mounted on pan/tilt heads. The centre of mass and specific kinematic variables were measured at push-off and touchdown for the first five strides. Descriptive statistics for all kinematic data were computed. The approach to using structural equation modelling with latent variable predictors was further refined and applied to the kinematic analyses of on-ice acceleration. Exploratory factor analyses were used to a) filter the set of predictor variables, and b) identify the underlying relationships between groups of kinematic variables. The results of the FA were examined to identify variables that grouped according to successive strides. When two repeated measures of a variable occurred in series (e.g. knee angle at push-off for stride one and stride two), the slope of the line was used to represent the composite of the two measures. When three or more measures of a repeated variable occurred in series (e.g. propulsive time for stride one, stride two, and stride three), a log-log transformation of the power function was used to transpose the raw scores within the variable series into a single composite score. Finally, multiple regression was used to determine the set of variables that best predict on-ice acceleration.

RESULTS AND DISCUSSION: A comparison of differences in the elite and development-age players showed that the elite skaters did not demonstrate a double support phase. The larger, more technically advanced skaters were able to apply a greater force in a shorter time period. Likewise, increased stride length for elite skaters was also a result of powerful propulsion. Conversely, development-age skaters demonstrated a double support phase that increased in time across strides. In general, we observed that there was greater variability among development-age skaters' technique. The application of the statistical approach enabled the researchers to produce a set of predictor variables while eliminating potential confounders. As a result variables with no/weak factor loadings were systematically removed, and a final regression model was constructed for each independent cohort and is presented in Table 1.

Table 1 Regression Models Derived From Independent Samples of Elite and Development-Age Skaters.

<table>
<tr><td colspan="2">Elite sample regression equation:
ſ = 0.291 + 0.845 X1 - 0.016 X2 + 0.007 X3 + 0.007 X4 + 0.453 X5 - 1.500 X6 – 1.698 X7 - 0.006 X8 - 0.004 X9

Development-age sample regression equation:
ſ = 1.283 + 0.004 X1 + 0 07 X2 - 0.246 X3 - 0.047 X4 - 0.094 X5 +0.062 X6</td></tr>
<tr><td>Elite Variables
X1 = Player Height
X2 = Peak Anaerobic Power (Normalized)
X3 = Knee Angle - 1st Push-off
X4 = Hip Abduction (Stride 4, 5)
X5 = Propulsive Time (Stride 2, 3, 4)
X6 = Stride Length (Stride 1, 2, 3)
X7 = Toe to C/M Distance - 3rd Touchdown
X8 = Hip Angle - 1st Push-off
X9 = Hip Abduction - 2nd Push-off</td><td>Development Age Variables
X1 = Knee Angle at Push-off 1-2
X2 = Knee Angle at Touch Down1
X3 = Take-off Angle at Push-off 1,2,3
X4 = Hip Abduction Angle at Push-off 5
X5 = Range of Motion of the Forward Lean Angle 2
X6 = Player Weight</td></tr>
</table>

In the sample of elite skaters, stride length, propulsive time, toe-to-hip distance at touchdown, range of knee extension, and player height were significant predictors as previously reported (Marino & Dillman, 1976, Pagé, 1976; Marino & Weese, 1979; Marino, 1984, de Koning et al., 1995). However, contrary to previous research (Marino & Dillman, 1976) lean angle at touchdown and takeoff angle at push-off were not significant predictors.

Comparatively, in the sample of development-age skaters, the kinematic parameters identified in the regression equation were related to the amount of horizontal impulse applied into the ice surface. Unlike the previous work of Marino (1983) and Purves (2000), measures of stride characteristic (stride rate, stride length, and propulsive time) were not identified. Player weight was identified as a significant predictor of time to skate six metres. Players that have a larger relative weight also have a physical advantage in the production of power during propulsion.

CONCLUSION: The use of a bivariate correlation matrix followed by exploratory factor analysis has been shown effective in the identification of kinematic parameters for the purpose of predicting time to skate six meters. Computations of slope and log-log transformations of the power function in order to transpose raw scores captured the progressive nature of the skating stride without masking the unique contributions of each individual stride. These results provide new information to the coach and player about the way in which body movements work together to predict performance.

REFERENCES:

de Koning, J.J., Thomas, R., Berger, M., de Groot, G., & Ingen Schenau, G.J. (1995). The start in speed skating: From running to gliding. Medicine, Science In Sports And Exercise, 27(12),1703-1708.

Marino, G.W. (1983). Selected mechanical factors associated with acceleration in ice skating. Research Quarterly, 54(3), 234-238.

Marino, G.W., & Dillman, C.J. (1976). Multiple regression models of the mechanics of the acceleration phase of ice skating. In Landry, F. and Orban, W.A.R. (Eds.) Biomechanics of Sports and Kinanthropometry. Book 6, Volume 6., International Congress of Physical Activity Sciences. Symposia Specialists Inc.: Miami, FL. pp. 193-201.

Purves, N.A. (2000). On-ice acceleration as a function of the Wingate Anaerobic test and a biomechanical assessment of skating technique, in elite ice hockey players. Unpublished Master's Thesis. Lakehead University.

Page, P.G. (1976). Biomechanical of forward skating in ice hockey. Unpublished Master's Thesis. Dalhousie University: Dartmouth, NS.