Paper : Fitness and Conditioning

Dynamic Causal Structure Analysis of Condition Fluctuation Factors in a Soccer Player

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[Received November 29, 2004 ; Accepted March 10, 2005]

The purpose of this study was to determine dynamic causal structure of condition fluctuation applying single case study design. A male 22 years-old college soccer player volunteered to participate in this study. His condition, training and sleeping were self-monitored for 71 days in the off-season training period using quality control (QC) sheets. Exploratory factor analysis (EFA) was utilized to extract condition fluctuation factors. The lag of condition fluctuation factors was analyzed using auto-correlation coefficients (AC) and partial auto-correlation coefficients (PAC) of condition fluctuation factor scores. The confirmatory factor model, the serial causal model, and dynamic causal model of condition fluctuation were analyzed using structural equation modeling (SEM). The model fitting indicators GFI, AGFI and NFI were utilized. Significant level was set up α = 0.05. It was statistically demonstrated that the condition fluctuation factors of the college soccer player in the off-season training period were constructed from condition, training, and sleeping, and there was dynamic causal structure with serial causal structure between these 3 condition fluctuation factors and lag 1 time delay of condition.

Keywords: conditioning, training, sleeping, structural equation modeling, single case study design

[Football Science Vol.2, 1-7, 2005]

1. Introduction

In order for athletes to improve their performance, it is important to enhance condition of their mind and body. Conditioning is a preparation process for performers to bring their current condition as close to their targeted level of condition as possible so that they can perform at their best during competition. In order to condition successfully, it is necessary to analyze condition factors that vary according to daily training.

Daily condition is related to the intensity or amount of training (Busso, et al., 1990; Morton, et al., 1990), and it is known that condition will be affected by athlete's daily lifestyle such as their diet and sleep (Nishijima, et al., 1990). In other words, condition fluctuation is time series data that are affected by multe variables. Therefore, it is appropriate to apply both multivariate analysis and time series analysis. Factors that affect series fluctuation of condition during training have been analyzed by applying analysis of variance (ANOVA) model, which is based on within-subjects design. However, individuality, which is very important information related to the accomplishment of conditioning by ANOVA model analysis, is processed as the accidental error. For the analysis focused on the individuality of condition fluctuation, it is desirable to apply single-case study design, and multivariate analysis and time series analysis for multivariate-time series data (Busso, et al., 1990; Morton, et al., 1990; Nishijima, et al., 2000; Ohba, et al., 1998).

By applying single-case study design and utilizing Quality Control (QC) sheets, it is possible to measure condition fluctuation that fits each individual (Nakano and Nishijima, 2001; Kinugasa, et al., 2002; Nishijima and Nakano, 2002; Nakano, et al., 2003; Nakano, et al., 2004). Based on correlation between multiple factors acquired as condition fluctuation factors, Nakano and Nishijima (2001) presumed that high-level latent factors are connected in the background among the acquired fluctuation factors, and determined the second factor structure using Structural Equation Modeling (SEM). Correlation among factors of condition fluctuation is sufficient condition when proving the second factor structure, however, it's not the required sufficient condition. Considering the fact that an athlete's condition is affected by his/her daily lifestyle including training, it is appropriate to state that correlation between factors of condition fluctuation factors shows causal relation. In other words, it is necessary to determine dynamic causal structure on condition fluctuation from the following perspectives; adequacy of condition fluctuation factors, serial causal relation and time series features.

The purpose of this study, therefore, is to clarify dynamic causal structure of condition fluctuation in a soccer player.

2. Procedure

2.1. Study subject

The subject of this study was a male college soccer player from Kanto university soccer league. He had been playing soccer for 7 years as a mid fielder. He was 22 years old and 168.0 cm tall and weighted 63.4 kg when measured for the study. The subject was given an explanation of the study regarding the research purpose, its significance and the possible risk of participating in the research, and he signed a consent form.

2.2. Measurement items and its period of time

In order to self-monitor condition fluctuation that is peculiar to the subject, the subject chose lifestyle items, such as training and sleeping, and condition items that include simple physiological indicator, such as body weight and heart rates. In reference to Nishijima et al. (1990), QC sheet was utilized to measure the subject's condition. The A4 sheet was made to record a week's-results on a single sheet, and it was kept with the subject to record his daily results. The analysis of this study was targeted for 71 days during the off-season training period which lasted for 10 weeks.

The domains chosen by the subject were condition of the mind and body, sleeping that affects his condition, and training. The sleeping item included the subject's bedtime and his hour of rising. The training items included training time, perceived will to training, perceived intensity of training, and perceived satisfaction of training. The items to monitor condition in mind and body included body weight when getting up, heart rate when getting up, perceived condition in the morning, perceived condition of training, and perceived condition in mind. The 5-point scale was applied to self-monitor perceived will to training, perceived intensity of training, perceived condition in the morning, perceived condition of training, and perceived condition in mind. A precise weight scale that is accurate to 0.1kg was used for the body weight measurements, and heart rate in beats per minute (bpm) was recorded.

2.3. Dynamic causal model

Busso et al. (1990) and Morton et al. (1990) have reported that fatigue from training appears earlier than the effects of training. They also showed by system analysis that condition decreases due to fatigue at an earlier stage of training and later it gradually recovers with the training effect when highly-intense training has been done for a certain period of time. Also, Kinugasa et al. (2002) reported that a well-portioned balance between training and rest is important in order to achieve a high-level of performance. The researchers also reported the effect of training can be expected according to the amount of training and that fatigue tends to accumulate. However, fatigue is overcome by taking a rest.

Considering the results by Busso et al. (1990), Morton et al (1990), and Kinugasa (2002), it can be stated that intense training evokes fatigue and lowers condition at a spontaneous t_1 point (negative causal relation) while having a good condition at t_0 point enables intense training at t_0 point (positive causal relation). At the same time, an appropriate rest at t_1 point improves condition at t_1 point (positive causal relation). That is, it could be stated that there is dynamic causal

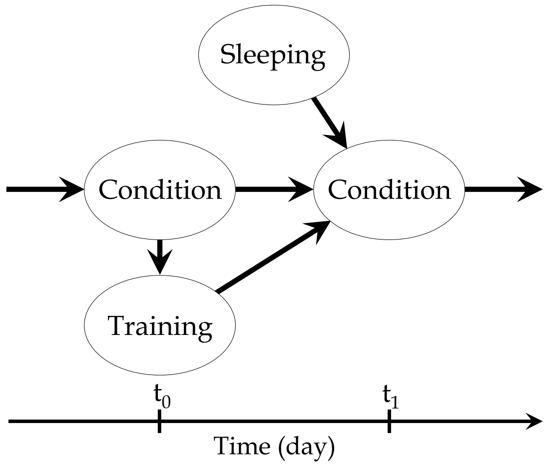

Figure 1 Conceptual model of condition fluctuation.

relation with time lag (In **Figure 1**).

2.4. Statistical analysis

Auto-correlation (AC) and partial auto-correlation (PAC) were calculated in order to process missing values that consider time series features for the measurement items. The time series fluctuation was determined by AC and PAC and the missing values were processed from the surrounding average values and from the series average.

In this study the first order system of AC and PAC from the previous day had the greatest effect, and the effects from more than 2 to 3 days before decreased exponentially. An effect from the previous was defined as Lag 1, the effect from 2 days before as Lag 2, and the effect from 3 days before was defined as Lag 3.

In order to extract factors lurking in time series fluctuation for multiple measurement items regarding condition, training, and sleeping, a multi factor model (Tsuda, 1994) was presumed and exploratory factor analysis (EFA) was conducted. Utilizing a maximum-likelihood method, factors whose eigen values were more than 1.0 were extracted. By performing promax rotation (Yanai, et al., 1995), factor pattern matrix and factor correlation matrix were obtained. Each factor was interpreted mentioning variables whose factor loading was more than 0.40 in factor pattern matrix. Confirmatory factor model was established referring to the factors obtained and the correlation between factors.

To determined causal relation between condition fluctuation factors, serial factor model of condition fluctuation was established, referring to correlation between factors in confirmatory factor structure and the preceding time. A factor score was determined from a factor score coefficient that was calculated by confirmatory factor analysis (CFA) of condition fluctuation factor, and the time series fluctuation in condition fluctuation factors was determined from the AC and PAC of each factor score. A regression method was used for the calculation of the factor score coefficient. The factor score was a standard score whose average value was calculated to be 0 and the standard deviation to be 1, and this is a score of an observed variable with a weighted score for each factor. To determine causal relation in terms of time series between condition fluctuation factors, dynamic factor model of condition fluctuation was established, referring to the time lag of condition fluctuation factors and time series features of serial factor structure that were determined by AC and PAC. The exploratory factor model, serial causal model, and dynamic causal model were dertermind utilizing SEM. GFI, AGFI and NFI that show coefficient of determination for data variance and covariance were used for the model fitting indication (Kano, 1997; Yamamoto, 1999). A significance level was set as $\alpha = 0.05$.

Table 1 Descriptive statistics.

Domain	Variables (unit)	N	Mean	SD	Max	Min
Sleeping	Bedtime (h:min)	69	24:38	1:29	33:00	22:00
	The hour of rising (h:min)	69	8:02	1:09	13:00	5:30
Training	Training time (min)	66	159.0	73.59	330.0	45.0
	Perceived will to training (1–5)	66	4.1	0.69	5.0	3.0
	Perceived intensity of training (1–5)	66	3.5	1.01	5.0	1.0
	Perceived satisfaction of training (1–5)	66	3.6	0.88	5.0	1.0
Condition	Perceived condition in the morning (1–5)	70	3.2	0.76	5.0	1.0
	Perceived condition of training (1–5)	66	3.4	0.79	5.0	2.0
	Perceived condition in mind (1–5)	70	3.8	0.49	5.0	2.0
	Body weight when getting up (kg)	70	63.0	0.46	64.0	62.0
	Heart rate when getting up (bpm)	70	47.6	3.29	60.0	42.0

Table 2 Auto-correlation (AC) and partial auto-correlation (PAC) coefficients of each variable.

Domain	Variable	Lag 1	Lag 2		Lag 3	
		AC (PAC)	AC	PAC	AC	PAC
Sleeping	Bedtime	0.162	0.153	0.131	0.071	0.029
	The hour of rising	0.157	0.190	0.170	−0.015	−0.070
Training	Training time	0.167	−0.062	−0.093	0.036	0.065
	Perceived will to training	0.052	−0.109	−0.112	0.059	0.072
	Perceived intensity of training	0.023	−0.063	−0.063	0.023	0.026
	Perceived satisfaction of training	0.072	0.054	0.049	0.160	0.153
Condition	Perceived condition in the morning	0.198	0.127	0.091	−0.004	−0.047
	Perceived condition of training	0.139	−0.053	−0.074	−0.011	0.007
	Perceived condition in mind	0.226*	0.222	0.181*	0.278	0.214*
	Body weight when getting up	0.244*	0.057	−0.002	0.075	0.065
	Heart rate when getting up	−0.073	0.074	0.069	0.115	0.126

*: $p < .05$

Table 3 Exploratory factor analysis of condition fluctuation factors: factor pattern matrix after promax rotation.

Variable	F1 Training	F2 Sleeping	F3 Condition	H2 Communality
Perceived intensity of training	1.00	0.00	0.01	0.99
Training time	0.80	0.00	−0.13	0.65
Perceived will to training	0.52	0.01	0.32	0.37
The hour of rising	0.04	1.00	0.01	1.01
Bedtime	−0.03	0.70	−0.05	0.50
Perceived condition of training	−0.09	0.04	1.03	1.06
Perceived condition in the morning	0.10	−0.18	0.41	0.21
Contribution of factor	1.92	1.54	1.34	4.79
Contribution rate of factor (%)	27.38	21.98	19.13	68.49
Correlation				
F2: Sleeping	−0.12			
F3: Condition	0.27	0.20		

3. Results

Table 1 shows descriptive statistics for the measurement items. Average values for perceived will to training, perceived intensity of training, perceived satisfaction of training, perceived condition in the morning, perceived condition of training and perceived condition in mind were in the range of 3.2 and 4.1. The average value (time) for bedtime was 24:38, and for the hour of rising was 8:02. The average training time was 159.0 minutes; 63.0 kg was the average body weight when getting up; 47.6 bpm was the average heart rate when getting up.

Table 2 AC and PAC of the measurement items. Significant values were shown in Lag 1, Lag 2 and Lag 3 for perceived condition in mind, and also shown in Lag 1 for body weight when getting up. No significant AC was observed in other items.

After EFA among 11 measurement items and the elimination of 4 items which had the least communality, EFA was conducted again among the remaining 7 items. **Table 3** shows factor pattern matrix and factor correlation matrix after a rotation. Three factors were acquired that explain a total

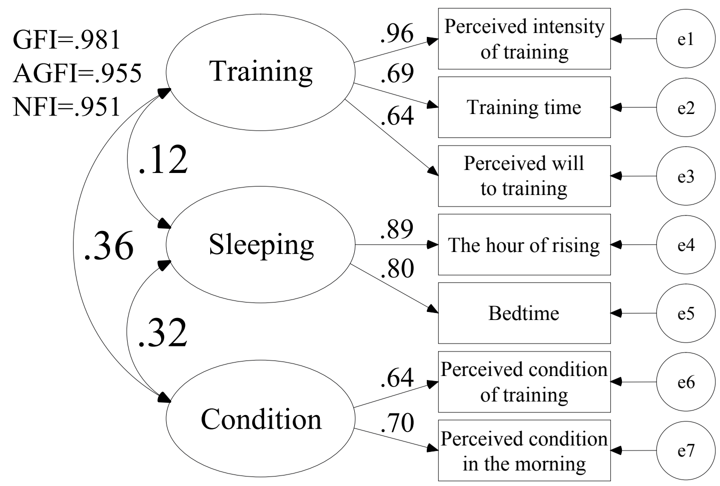

Figure 2 Confirmatory factor structure of condition fluctuation factors.

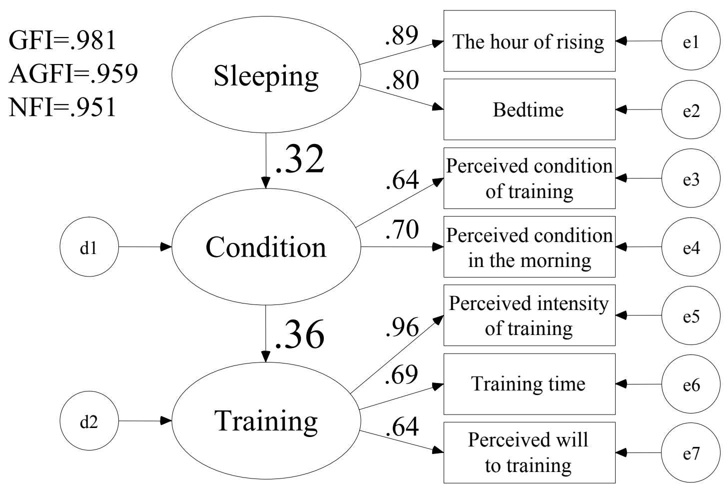

Figure 3 Serial causal structure of condition fluctuation.

Table 4 Auto-correlation (AC) and partial auto-correlation (PAC) coefficients of each factor score.

Factor	Lag 1	Lag 2		Lag 3	
	AC (PAC)	AC	PAC	AC	PAC
Training (F1)	0.128	0.082	0.067	0.059	0.041
Sleeping (F2)	0.045	−0.052	−0.054	0.027	0.033
Condition (F3)	0.365*	0.175	0.048*	0.017	−0.071*

*: $p < .05$

variance of 68.49% for the 7 items. A first factor was interpreted as a factor that has a relation with training fluctuation (training), for it showed a high factor loading in perceived intensity of training, training time and perceived will to training. A second factor was interpreted as a factor that has relation with sleeping fluctuation (sleeping), for it showed high factor loading for the hour of rising and bedtime. A third factor was interpreted as a factor that has relation with condition fluctuation (condition), for it showed high factor loading in perceived condition of training and perceived condition in morning.

Figure 2 shows a standardized solution of confirmatory factor structure of condition fluctuation factors. GFI, which is model fitting indicator, was 0.981, AGFI was 0.955 and NFI was 0.951. All path coefficients were significant between latent variables and observed variables. A path coefficient from training to perceived intensity of training was 0.96, 0.69 to training time and 0.64 to perceived will to training. A path coefficient from sleeping to the hour of rising was 0.89, 0.80 to bedtime. A path coefficient from condition to perceived condition of training was 0.64 and 0.70 to perceived condition in the morning.

Figure 3 shows a standardized solution of serial causal structure of regarding condition fluctuation. GFI was 0.981, 0.959 for AGFI and 0.951 for NFI. Path coefficients between latent variables were all significant. A path coefficient from sleeping to condition was 0.32. It was 0.36 from condition to training.

Table 4 shows AC and PAC of each factor score regarding CFA. Lag 1, Lag 2 and Lag 3 showed significance in AC for condition, and Lag 1 showed the highest value for PAC. No significant value was shown in AC for training and sleeping.

Figure 4 shows a standardized solution of dynamic causal structure of condition fluctuation. GFI was 0.966, 0.937 for AGFI and 0.911 for NFI. All path coefficients between latent variables were significant. A path coefficient from condition (t_0) to training (t_0) was 0.38, 0.51 was to condition (t_1). A path coefficient from training (t_0) to condition (t_1) was -0.38, and 0.32 from sleeping (t_1) to condition (t1).

4. Considerations

EFA was conducted using the multivariate time series data that had missing value processing, based on AC and PAC in the measurement items (**Table 2**), and three factors have been acquired which are related to condition fluctuation (condition), training fluctuation (training) and sleeping fluctuation (sleeping). The details of these condition fluctuation factors were different from those of research done before (Ohba, et al., 1998; Nakano and Nishijima,

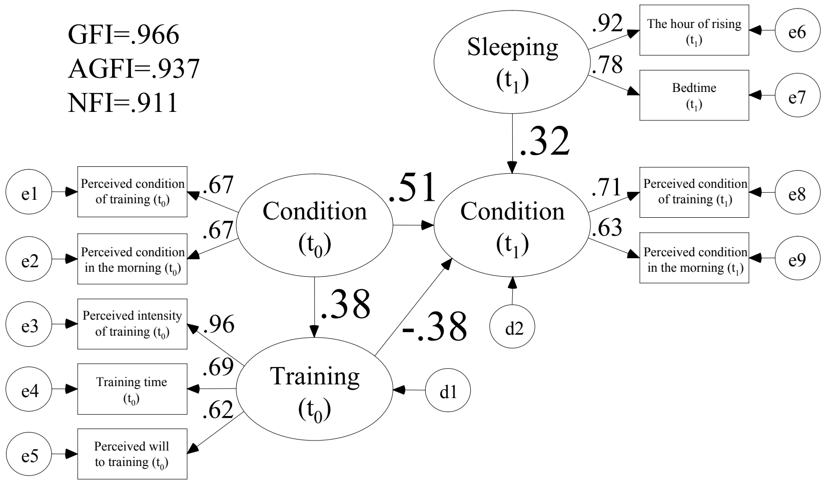

Figure 4 Dynamic causal structure of condition fluctuation.

2001). Variant coefficient of determination for the three factors, which was 68.49%, was the same as the research done before. Considering the fact that condition fluctuation involving training greatly reflects each individual (Nishijima, et al., 2000), it can be stated that these three factors are unique to the subject of this study and they reflect a condition fluctuation feature.

Serial causal structure of condition fluctuation showed causal relation based on the preceding time: condition from sleeping, and training from condition. Serial causal structure showed a high value in goodness of fit, and serial causal relation was determined regarding condition fluctuation. It has been clarified that an appropriate amount of sleep affects condition in terms of maintaining and improving it, and his condition is affected by the intensity and the amount of training.

As a result of determining time series features regarding condition fluctuation factor, AC in condition showed significant values in Lag 1, Lag 2 and Lag 3. It can be stated that the time series feature for condition is a first order system because PAC showed a great decrease after Lag 2. No significant AC and PAC regarding training nor sleeping were observed. The type of training is generally planed by an instructor with a medium to long term view, and the everyday training was set up by each individual. Sleeping is known to affect maintaining and improving condition; therefore, it is necessary to get an appropriate number of hours of sleep everyday. Because of these reasons, it was assumed that there was no significant AC and PAC observed in both of those factors.

A model fitting indicator of dynamic causal structure of condition fluctuation showed good values, and dynamic causal relation between fluctuation factors has been determined. A significant positive path coefficient (0.36) between condition and training for serial causal structure was determined. For dynamic causal structure considering the time lag, the relationship between condition and training within the same day (t_0) showed a path coefficient (0.38) which was similar to that of serial causal structure. A path coefficient from training (t_0) to condition next day (t_1) showed a significant negative value (-0.38). It can be concluded that there is a mutual dependence relation between condition and training because a significant positive path coefficient (0.51) between condition (t_0) and condition (t_1) has been acquired. The result gained from above matched with a report by Morton et al. (1990) and Busso et al. (1990) that, using system analysis, describes dose-response relationship between training and subject's performance utilizing physiological indexes (oxygen uptake, heart rate). Therefore, dynamic causal relation was clarified that the good condition enables intense training while intense training evokes fatigue which lowers condition the next day.

On the contrary, sleeping (t_1) showed a significant positive path coefficient (0.32) to condition (t_1) from the same day and maintaining condition was made possible by going to bed early and getting up early in order to get enough hours of sleep. Sleeping is one important element that lets body and mind recover from fatigue and condition oneself (Kobayashi, 1995). One fatigue soothing effect of sleep includes the secretion of growth hormones. The growth hormones work to recover and strengthen weary muscle fibers that were used during training.

Secretion of growth hormones is known to have a significant relation with training intensity and sleeping time (Godfrey, et al., 2003) and growth hormones secret the most for only about three hours from 11 p.m. to 2 a.m. Therefore, it can be concluded that sleeping is an effective way to improve condition that is weakened by intense training.

From all of the above,dynamic causal relation between condition and training has been demonstrated that changes as time passes. In order to improve two important aspects of physical conditioning, which are fatigue recovery and the improvement of latent ability, the following are considered to be very important: going to bed before 11 p.m. and getting the appropriate number of hours of sleep because sleeping keeps in good condition and enables intense training and that is an important factor.

Lastly, the conclusions acquired from this study do not necessarily apply all soccer players because the study has examined a causal structure of condition fluctuation for a single soccer player, utilizing single-case study design. Dynamic causal structure determined in the study can be adaptable to a causal structure of condition fluctuation for numbers of soccer players, however, path coefficient, AC and PAC in dynamic causal structure are not common. An issue left for the future is to compare and examine causal structure of condition fluctuation among other soccer players and players from different age groups.

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