Multitrait Factor Structure of Control Tests for Power Development Program in Soccer

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The purpose of this study was to apply the multitrait factor structure model to the control test used for the power development program for soccer players that is hierarchically constructed and to confirm contributions of the task motor skill to the test performance. Subjects were 103 male college soccer players tested on 15 items selected by qualitative characteristic attribution analysis to construct a hypothetical structure of the control test following the power training phase. Test-retest reliability of the power tests was examined. The feasibility of the multitrait factor structure model was confirmed with the structural equation modeling. It was made apparent how power and skill factors were involved in the test performance. We concluded that multiple power subdomains and multiple motor skill domains are involved in control tests consisting of multiple motor tasks. The power and skill differ in contributions in each test. There is a relationship between motor skills involved in test performance, which becomes the basis of control test arrangement.

Keywords: structural equation modeling, power development program, performance test, motor task, motor skill

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1. Introduction

When physical fitness and motor ability are measured with performance tests, test performances are related to skills unique to motor tasks. These skills have a common effect on multiple tests for the same motor task and their difference can be assumed to be a systematic error. It is necessary to separate the skill level of the motor task involved in test performance to clarify the control test validity of the control test consists of multiple motor tasks. The control test is used to confirm the progress of motor skills by the training program. However, no report has verified the validity of taking into account the effect of the task motor skill.

For the Radex [radial expansion of complexity theory proposed by Guttman (1954)], the domain structure consists of a circumflex with circulating order between tests and a simplex with sequence and hierarchy between series of tests. Marcus et al. (1985) confirmed the Radex structure between neurologically dysfunctioning tests in the offspring of schizophrenics. Mills (1985) applied the Radex structure to the confirmation of Maslow’s hierarchical structure in the motivations of skiers. Li et al. (1996) applied the simplex structure to the confirmation of hierarchy in the Sport Motivation Scale. No study exists to our knowledge, however, that applies the Radex structure between physical fitness and motor ability tests, but Larson (1951) assumed hierarchy in the motor ability structure. Since physical fitness and motor ability are measured by performance tests using different types of motor tasks, the Radex structure is considered established between physical fitness and motor ability tests. The development of specialized physical fitness and motor ability is measured by the control test [Nishijima (1994a)]. The final goal of training is improved skill in sports [Ishii (1998)] and the training program is hierarchically built up from basic to specialized steps. The control test is constructed by performance tests for different motor tasks in response to the training phase. Consequently, a hierarchy is required between test performances. Yamada and Nishijima (2002) applied the simplex structure to the confirmation of the hierarchy between control tests in the power development program for soccer players. However, the effect of multiple motor tasks was not confirmed involved in test performance.

Control tests in the power development program for soccer players consist of the following typical tests: medicine ball throw, vertical jump, and 30 m sprint [Nishijima (1994)]. Since these tests have unique skill
requirements [Mayhew et al. (1989)], the test performance reflects the pattern and specificity of a motor task [Manning et al. (1988)]. Thus, it is necessary to take into account the relationship of the motor task skills to test performance when selecting tests and to reduce errors due to skill to accurately evaluate power development at each phase of a training program.

Errors due to the measurement test trait and method factors can be separated [Kano (1997)] by analyzing the multitrait-multimethod (MTMM) model in the framework of structural equation modeling (SEM)[Marsh et al. (1988); Toyoda (2000); Yamamoto and Onodera (1999); Rose et al. (2001)] describe the development and concurrent validity of the Exercise Causality Orientations Scale (ECOS) and variances of the question were separated into traits of causality orientation and error by questions by applying the MTMM model. Marsh (1996) applied the MTMM model to test for the convergent and discriminant validity of Physical Self-Description Questionnaire (PSDQ) responses and variances of the question were separated into traits of physical status and errors by time answer. The effect of the power factor and error of the skill factor are separated to compare the contribution of power factors with that of skill factors in test performance by analyzing a multitrait factor structure model consisting of multiple power and task motor skill traits measured by the control test in the SEM framework through the application of the MTMM model. This study was to confirm the contribution of motor task skills involved in test performance by applying the multitrait factor structure model to the control test used in the power development program built up hierarchically.

2. Methods

2.1. Samples

Subjects were 103 male college soccer players 172.6 ± 5.1 cm tall, weighing 67.0 ± 5.2 kg, aged 20.0 ± 0.9 years, and having a playing experience of 10.8 ± 2.3 years.

2.2. Procedures

The following procedures were implemented to confirm the multitrait factor structure model in the control test:

(1) Constructing the hypothetic structure of the power test based on the training phase
(2) Selecting tests
(3) Implementing tests

Fig. 1. Qualitative structure of the control tests for power development program in soccer.

(4) Reviewing the reliability of the test-retest method
(5) Confirming the factor structure by SEM (confirmatory factor analysis model, multitrait factor structure model)

2.3. Measurement Items

To select items that satisfied content validity, we used qualitative characteristic attribution analysis in conformance with Nishijima (1993) to construct a control test corresponding to the power training phase hierarchically constructed and the hypothetical structure of the power and skill domains involved in motor tasks of the test, and presented them in fish-bone diagrams (Fig. 1). The power training phase was assumed for four consecutive domains: functional strength, countermovement of ballistic/priometric, rebound of ballistic/priometric, and over speed. The power domain involved in each training phase was assumed for four power subdomains: lifting, countermovement, rebounding, and sprinting. The test of each subdomain was placed in the fish-bone diagram and the skill domain involved in the test shown. The selected test was composed of 15 items: 3-repetition maximum (3RM) of the bench press, squat 3RM, 20 kg resisted vertical jump, and 20 kg resisted sprint jump in lifting subdomain, medicine ball back throw, medicine ball side throw, vertical jump, and standing long jump in the countermovement subdomain, vertical drop jump, forward drop jump, 5-step jump, and 5-step jump with both legs in the rebounding subdomain, and 30 m sprint, 50 m sprint, and 30 m × 4 shuttle run in the sprinting subdomain.

2.4. Models

The confirmatory factor analysis (CFA) model was applied to construction of the skill factor structure.
Table 1. Mean, SD and reliability of control tests for power development program in soccer (N=103).

<table>
<thead>
<tr>
<th>Training phase</th>
<th>Power domain</th>
<th>Skill domain</th>
<th>Control tests</th>
<th>Mean</th>
<th>SD</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional strength</td>
<td>Lifting power</td>
<td>Lifting</td>
<td>Bench press JRM (kg)</td>
<td>63.0</td>
<td>8.1</td>
<td>.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lifting</td>
<td>Squat JRM (kg)</td>
<td>113.4</td>
<td>14.7</td>
<td>.78</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jumping</td>
<td>20kg resisted vertical jump (cm)</td>
<td>37.0</td>
<td>3.6</td>
<td>.96</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jumping</td>
<td>20kg resisted sprint squat jump (cm)</td>
<td>38.0</td>
<td>4.5</td>
<td>.94</td>
</tr>
<tr>
<td>Ballistic/priometric (Counter movement type)</td>
<td>Counter movement power</td>
<td>Throwing</td>
<td>Medicine ball side throw (m)</td>
<td>9.5</td>
<td>1.2</td>
<td>.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Throwing</td>
<td>Medicine ball side throw (m)</td>
<td>10.6</td>
<td>1.4</td>
<td>.92</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jumping</td>
<td>Vertical jump (cm)</td>
<td>50.6</td>
<td>6.5</td>
<td>.96</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jumping</td>
<td>Standing long jump (cm)</td>
<td>242.8</td>
<td>16.1</td>
<td>.95</td>
</tr>
<tr>
<td></td>
<td>Rebounding power</td>
<td>Jumping</td>
<td>Forward drop jump (cm)</td>
<td>227.5</td>
<td>10.6</td>
<td>.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jumping</td>
<td>5 steps jump (m)</td>
<td>12.3</td>
<td>0.6</td>
<td>.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jumping</td>
<td>5 steps jump with both legs (m)</td>
<td>12.2</td>
<td>0.7</td>
<td>.87</td>
</tr>
<tr>
<td>Over speed</td>
<td>Sprinting power</td>
<td>Sprinting</td>
<td>30 m sprint (m/s)</td>
<td>7.0</td>
<td>0.2</td>
<td>.92</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sprinting</td>
<td>50 m sprint (m/s)</td>
<td>7.5</td>
<td>0.2</td>
<td>.94</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sprinting</td>
<td>30 m X 4 shuttle run (m/s)</td>
<td>5.7</td>
<td>0.1</td>
<td>.75</td>
</tr>
</tbody>
</table>

Fig. 2. Factor structure of skill of the control tests.

2.5. Statistical Analysis

The reliability of the test was considered by the test-retest method. Three models were confirmed using SEM. Parameters were fixed to secure identification of each model. The fix conditions were a) to fix the pass coefficient from an error variable to an endogenous variable to 1, b) the variance of the latent variable that is an exogenous variable to 1, and an error variance predicted a negative value to 0. The significance of the pass coefficient was considered by the critical ratio (CR) to delete an insignificant pass. Modification was performed to add the covariation between error variables in a range without impairing the meaning of models based on modification indices used in Amos4.0J. The following were used for the model goodness of fit indices: GFI, AGFI, chi-square (CHI-SQ), P value, degree of freedom (DF), RMSEA, AIC, NFI, and CFI. The factor contribution was found for the test by the square of the pass coefficient from the factor (latent variable) to the test (observed variable). All the statistical significant levels were made 5%. Amos4.0J and SPSS11.0 were used for statistical processing.
3. Results

3.1. Reliability

Table 1 lists the mean, standard deviation, and reliability of each test. The mean of standing long jump is 242.8 (±16.1) cm and largely exceeds the mean of 20 to 24 years old that is 228.3 (±23.3) cm in the physical fitness and motor ability survey by the Ministry Education, Culture, Sports, Science and Technology of Japan (MEXT, 2002). The reliability coefficient by the test-retest method showed a high of at least 0.75 for each test.

3.2. Factor Structure

Figure 2 shows the standardized solution of the skill factor structure model (model 1). The model had goodness of fit indices: GFI=0.891, AGFI=0.832, CHI-SQ=106.14 (p=0.019), DF=78, RMSEA=0.059, AIC=190.14, NFI=0.883, and CFI=0.965. The pass coefficient from the skill factor to the power test showed 0.54 to 0.92. Any pass in the model was significant with a level of 5%.

Figure 3 shows the standardized solution of the power factor structure model (model 2). The model had goodness of fit indices: GFI=0.871, AGFI=0.812, CHI-SQ=125.85 (p=0.001), DF=79, RMSEA=0.076, AIC=207.85, NFI=0.861, and CFI=0.942. The pass coefficient from the power factor to the test showed 0.41 to 0.89. Any pass in the model was significant with a level of 5%.

Figure 4 shows the standardized solution of the multitrait factor structure model (model 3). The model had goodness of fit indices: GFI=0.905, AGFI=0.839,
Table 2. Comparison among models by goodness of fit indices of structural equation modeling.

<table>
<thead>
<tr>
<th>Goodness of fit indices</th>
<th>Skill model</th>
<th>Power model</th>
<th>Multitrait model</th>
</tr>
</thead>
<tbody>
<tr>
<td>GFI (Goodness of Fit index)</td>
<td>0.891</td>
<td>0.871</td>
<td>0.905</td>
</tr>
<tr>
<td>AGFI (Adjusted Goodness of Fit index)</td>
<td>0.832</td>
<td>0.812</td>
<td>0.839</td>
</tr>
<tr>
<td>CHI-Square</td>
<td>106.14</td>
<td>125.85</td>
<td>73.15</td>
</tr>
<tr>
<td>DF (degree of freedom)</td>
<td>78</td>
<td>79</td>
<td>71</td>
</tr>
<tr>
<td>P-value</td>
<td>0.019</td>
<td>0.001</td>
<td>0.407</td>
</tr>
<tr>
<td>RMSEA (Root Mean Square Error of Approximation)</td>
<td>0.059</td>
<td>0.076</td>
<td>0.019</td>
</tr>
<tr>
<td>AIC (Akaike Information Criterion)</td>
<td>190.14</td>
<td>207.85</td>
<td>171.15</td>
</tr>
<tr>
<td>NFI (Bentler-Bonett Normed Fit Index)</td>
<td>0.883</td>
<td>0.861</td>
<td>0.905</td>
</tr>
<tr>
<td>CFI (Comparative Fit Index)</td>
<td>0.965</td>
<td>0.942</td>
<td>0.997</td>
</tr>
</tbody>
</table>

Skill model: skill factor structure model.
Power model: power factor structure model.
Multitrait model: multitrait factor structure model consisted of skill and power factors.

Table 3. Degrees of contribution of power and skill factors to the control test performance in multitrait factor structure.

<table>
<thead>
<tr>
<th>Power domain</th>
<th>Skill domain</th>
<th>Control tests (unit)</th>
<th>Power</th>
<th>Skill</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifting</td>
<td>Lifting</td>
<td>Bench press 3RM (kg)</td>
<td>-</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Lifting</td>
<td>Squat 3RM (kg)</td>
<td>21</td>
<td>33</td>
<td>46</td>
</tr>
<tr>
<td>Power</td>
<td>Jumping</td>
<td>20 kg resisted vertical jump (cm)</td>
<td>26</td>
<td>48</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Jumping</td>
<td>20 kg resisted sprint squat jump (cm)</td>
<td>-</td>
<td>32</td>
<td>68</td>
</tr>
<tr>
<td>Counter</td>
<td>Throwing</td>
<td>Medicine ball side throw (m)</td>
<td>-</td>
<td>51</td>
<td>49</td>
</tr>
<tr>
<td>movement</td>
<td>Throwing</td>
<td>Medicine ball side throw (m)</td>
<td>4</td>
<td>77</td>
<td>19</td>
</tr>
<tr>
<td>power</td>
<td>Jumping</td>
<td>Vertical jump (cm)</td>
<td>42</td>
<td>58</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Jumping</td>
<td>Standing long jump (cm)</td>
<td>-</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>Rebounding</td>
<td>Jumping</td>
<td>Vertical drop jump (cm)</td>
<td>-</td>
<td>44</td>
<td>56</td>
</tr>
<tr>
<td>power</td>
<td>Jumping</td>
<td>Forward drop jump (cm)</td>
<td>-</td>
<td>57</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Jumping</td>
<td>5 steps jump (m)</td>
<td>41</td>
<td>59</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Jumping</td>
<td>5 steps jump with both legs (m)</td>
<td>4</td>
<td>57</td>
<td>40</td>
</tr>
<tr>
<td>Sprinting</td>
<td>Sprinting</td>
<td>30 m sprint (m/s)</td>
<td>39</td>
<td>61</td>
<td>-</td>
</tr>
<tr>
<td>power</td>
<td>Sprinting</td>
<td>50 m sprint (m/s)</td>
<td>9</td>
<td>64</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Sprinting</td>
<td>30 m × 4 shuttle run (m/s)</td>
<td>-</td>
<td>53</td>
<td>47</td>
</tr>
</tbody>
</table>

1) error variances were fixed zero to bind parameters.

CHI-SQ=73.15(p=0.407, DF=71, RMSEA=0.019, AIC=171.15, NFI=0.905, and CFI=0.997. The pass coefficient from power and skill factors to the test showed 0.21 to 1.00. A significantly high correlation coefficient of 0.74 was obtained between skill factors, that is, jumping and throwing skills. A significant correlation was not obtained with a value of 0.18 between weight lifting and sprinting skills. The pass coefficient was significant with a level of 5% in the model except for part of the interfactor correlation.

Table 2 shows a comparison of goodness of fit indices between models. The multitrait factor structure model (model 3) indicated the best value in the goodness of all fit indices. In particular, it had the lowest AIC indicating the relative merits between models and its chi-square was insignificant for certifying the independence of a model. From these results, the multitrait factor structure model (model 3) was determined to be the most adequate.

Table 3 shows the contribution of each model in the multitrait factor structure model for the test. The contribution of the skill factor was larger than that of the power factor in all tests.
4. Discussion

This study placed 15 tests with content validity in the power subdomain assumed based on the training phase. A reliability coefficient of at least 0.75 was obtained in all tests.

As a result of confirming three models and making a comparison between their goodness of fit indices, the multitrait factor structure (model 3) consisting of power and skill factors was determined to be the most adequate model. This indicates that the test performance is affected by both power and skill. The contribution of each factor in the multitrait factor structure model for tests was higher for the skill factor than for the power factor in all tests. It became apparent that skill was involved largely in test performance.

In addition, model 2 showed a better value than model 1 in the goodness of fit indices and the pass coefficient from the power factor dropped in model 3 compared to model 2. This led apparently to the fact that skill was involved more largely in test performance. Mayhew et al. (1989) indicated that the skill of motor ability affected the performance test measuring power qualitatively. This study applied the multitrait factor structure model to quantitative confirmation of the degree of skill involvement in test performance.

The contribution of the power factor in the multitrait factor structure model was smaller than that of the skill factor. As shown in the relationship between vertical jumping height and the maximum or mean power by Johnson and Bahmonde (1996), we verified that the degree of the power factor involved in test performance is generally large. The effect due to physical fitness and motor ability properties of samples can be considered as the cause that showed that the degree of the skill factor involved in the motor task of the test was larger than that of the power factor to be tested. Muraki (1985) said that higher-level jumpers were characterized by a remarkable increase in specialized training such as technical practices. With progress in development of specialized training, differences in skills increase between individuals, while differences in power, the basic ability, decrease between individuals. Samples can be considered as a group with a high-level of development of soccer training because their playing experience was 10.8±2.3 years and standing long jump was 242.8±16.1 cm, which was greater by 1SD than the national mean.

It was considered the relationship among skills involved in the control test for the power development program from the correlation among skill factors in the multitrait factor structure model. A significant high correlation coefficient was obtained between jumping and throwing skills. The jumping skill had an intermediate or more correlation coefficient with all skills. Since extension of the lower limb is common to jumping, squat, medicine ball throw, and sprinting, jumping skill is presumed to have a high correlation with any other skill. No significant correlation coefficient was obtained between weight lifting and sprinting skills. A significantly low correlation coefficient was obtained between throwing and sprinting skills. From these results, the specificity of a skill was presumed to influence them, for example, no sprinting is required for weight lifting or throwing and the accuracy of the upper limb requested for throwing is not required for sprinting.

When skills with a high correlation were made consecutive and those with low correlation were isolated based on the results above, weight lifting, throwing, jumping, and sprinting skills were arranged in this order. We confirmed that jumping skill was positioned near any other skill. In other words, when the control test is arranged in response to the power-training phase, it may be appropriate that jumping is mainly selected and that the test by sprinting such as 30 m sprint is arranged continuously with the test by jumping.

Guttmann (1954) states that the incomplete circumflex, that is, semicircumplex structure, indicates the simplex structure. Since the correlation between skill factors shows a series of sequence, we presumed that a simplex structure is formed between them. This implies that the circumflex structure between different types of skills is incomplete, which may be a ground for formation of a radex structure between control tests for power development.

The contribution of each factor for the test made apparent the degree of power and skill involvement in each test. Squat 3RM had the same degree of power involvement as 20 kg resisted vertical jump in the lifting power domain, but the latter had a larger degree of skill involvement. From these results, 20 kg resisted vertical jump was presumed to be a motor task requiring the involvement of many skills compared to squat 3RM in terms of the necessity of motor control under a faster motion.

Vertical jump had a larger degree of power involvement than medicine ball back throw in the countermovement power domain, while the former had a larger degree of skill involvement. Medicine ball back throw is a throwing event and is a motor task that requires the involvement of many skills in motor control including the accuracy of adjusting a projection angle and a group of upper limb muscles. Since vertical jump does not require skills in a relative manner, it may have a larger degree of power involvement.

The 5-step jump with both legs had a larger degree
of power involvement than the 5-step jump in the lifting power domain, while the former and the latter had the same degree of skill involvement. Since the 5-step jump is a motion with one leg support compared to the 5-step jump with both legs, it may have a relatively large degree of skill involvement.

The 30 m sprint had a larger degree of power involvement than 50 m sprint in the sprinting power domain, while the former and the latter had the same degree of skill involvement. Oghushi et al. (1981) reported that soccer players reached the highest speed with a short distance of 30 to 40 m compared to tack and field players. The 30 m sprint consists of the acceleration phase, while the 50 m sprint consists of acceleration and constant speed phases. From these results, we verified that more power involvement was required in the acceleration phase and that skill involvement was requested in the constant speed phase in addition to power involvement.

This study applied the multitrait factor structure model consisting of power and skill factors in the control test used for the soccer power development program that was hierarchically built up to the confirmation of task motor skill involvement in the test performance. As a conclusion, multiple power subdomains and multiple skill domains are involved in the control test consisting of multiple motor tasks. The degree of power and skill involvement differs in each test. A relationship exists between skills involved in test performance, which becomes a ground for the hierarchical selection of the control test in response to multiple training phases.

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