Genetic and Environmental Effects on Physical Fitness and Motor Performance

Enji Okuda*, Daisuke Horii** and Toshifumi Kano***

*Associate Professor, Faculty of Education, Shiga University
2-5-1 Hiratsu, Ohtsu, Shiga 520-0862 Japan
okuda@sue.shiga-u.ac.jp
**Lecturer, Seian University of Art and Design
4-3-1 Ohginosato, Higashi, Ohtsu, Shiga 520-0248 Japan
***Professor, Faculty of Social Welfare, Kogakkan University
7-1 Kasugaoka, Nabari, Mie 518-0498 Japan

[Received August 20, 2003 ; Accepted October 1, 2004]

The purpose of this study was to estimate genetic and environmental effects on physical fitness and motor performance. Subjects for this study were 90 pairs of monozygotic twins (MZ) and 68 pairs of dizygotic twins (DZ), a total of 316 subjects between 10 to 15 years old. Six items were used for physical fitness and motor performance data: grip strength, sit-ups, sit and reach, side step, 50 meter run and standing broad jump. The correlation analysis and the model-fitting analysis have been done based on the type of each set of twins. For the model-fitting analysis, models that give effects of additive genes (A), nonadditive genes (D), common environment (C), and specific environment (E) on phenotypes of physical fitness and motor performance have been applied. The following could be presumed as a result of a correlation analysis: the results showed for the grip strength and the side step that $r_{MZ}$ was greater than $r_{DZ}$, and $r_{DZ}$ was greater than half of $r_{MZ}$, therefore, it could be stated that there were effects from additive genetic and common environmental factors. The results from the sit-ups and the 50 meter run showed that $r_{MZ}$ and $r_{DZ}$ were almost equal to each other, therefore, it could be stated that there was no genetic effect. The correlation ratio of $r_{DZ}$ and $r_{MZ}$ was 2:1 for the category of sit and reach, therefore, the resemblance among MZ was from the genetic effect only. As for the standing broad jump, $r_{DZ}$ was smaller than half of $r_{MZ}$, therefore, there were effects of additive genetic and nonadditive genetic factors. From the results of the model-fitting analysis, the following could be stated: the best fitting models for grip strength, sit and reach, and the standing broad jump, where additive genetic and specific environmental factors affect phenotypes, were the AE model, and the coefficient of determination of additive genetic factor, at between 52.2% and 76.9%, was relatively high. For the side step, where additive genetic, common environmental and specific environmental factors have effects on phenotypes, the best fitting model was the ACE model, and each coefficient of determination was 32.4%, 39.4% and 28.1%. No genetic effect was observed for sit-ups and the 50 meter run. The coefficient of determination for sit-ups was 51.1% in a common environment and was 48.9% in a specific environment. S-CE was the best fitting model for the 50 meter run, where the effect varies depending on sex, and the coefficient of determination for boys were 75.5% for common environment and 24.4% for specific environment, whereas those for girls were 53.0% and 46.9% respectively.

Keywords: physical fitness and motor performance, genes, environment, twin study, model-fitting analysis

1. Introduction

Before investigating any environmental factors that affect the development of physical fitness and motor performance (hereupon referred to as physical fitness), it is necessary to clarify the heritability of physical fitness. However, there is very little research on the heritability of physical fitness compared to research on intelligence and personality, therefore it is not possible to state that one stable conclusion...
exists. Furthermore, there is very little research that tries to categorize the separate effects of genes and environment on each individual’s physical performance.

In order to investigate genetic effects on people’s behavioral characteristics, approaches such as the top-down approach, whose estimation is based on phenotypes, and the bottom-up approach, whose estimation is based on genes which are related to phenotypes (Bouchard et al., 1997), are used. "Phenotypes" are sometimes referred to as observed characteristics, which are observable variables such as height and body weight. In the top-down approach, genetic effects are studied by comparing phenotype resemblances between relatives such as twins, parent-child and siblings. Among those studies, twin study is the most common. The basic idea of this style of study is that if a phenotype of a pair of monozygotic twins (MZ), who are genetically 100% identical, has more resemblance than that of dizygotic twins (DZ), who are genetically only 50% identical, then that phenotype can be said to have genetic effects.

In the study of the top-down approach regarding the genetic effects on physical fitness, there has been a shift in research from previous studies, such as within-pair difference, correlation analysis, heredity index and analysis of variance, to a path analysis based on gene models, and most recently to a model-fitting analysis. In reviews of previous studies there is a great deal of inconsistency among the results of research carried out in various countries, and the conclusions drawn from those various results reveal that the level of genetic effects on many characteristics of physical fitness is merely moderate (Wolanski, et al.,1980; Malina, 1986; Bouchard, et al., 1997). It is also difficult to elicit a conclusion other than the one above from the research conducted in Japan (Kimura, 1956; Mizuno, 1956, Suetoshi and Minobe, 1958; Higuchi et al., 1977; Nakayama 1987).

In recent studies, analyses have been performed based on a model that presumes factors such as additive genes (A), nonadditive genes (D), common environment (C) and specific environment (E). Additive genes means that each gene affects a phenotype evenly, and that its effect simply adds up for each gene. Contrarily, nonadditive genes shows different meanings and effects according to combinations of genes, and cannot be explained with simple addition like additive genes. The relative contribution that genes have when setting a phenotypic value is called the heritability (heritability: h²) of its character, and it is defined as the proportion of phenotypic variance attributable to genetic effects. As for environmental factors, they are broadly categorized into two components, with one component working to give a similarity to each member of the same family, which means that the factors that differentiate one family from another are found in the common environment and another component that work to differentiate each family member in the same family are found in the specific environment.

There are analysis models such as the TAU model (Devor and Crawford, 1984; Peruse et al., 1988), the BETA model (Perusse et al., 1987a; Perusse et al., 1987b), the ACE model (Fagard et al., 1991; Peter et al., 1999) and the ADCE model (Maes et al., 1993; Thomiset al., 1998). The formula for the TAU model is P=T+E, and the phenotype consists of T, which is a percentage of an effect that is passed on to a child from its parents, and E, which is the percentage of the effect a child has not been inherited from its parents. T is a sum of effects for both additive genetic and common environmental factors, but it does not distinguish one from the other. The BETA model distinguishes these effects. The formula for the BETA model is P=A+B+E. A is for additive genetic factor, B for common environmental factor, (T when the effects are the sum of both A and B that a child inherits from its parents,) and E for the environmental factor not inherited. The BETA model consists of additive genetic, common environmental and specific environmental factors, therefore, it is the same as the ACE model. When a latent variable of nonadditive genetic factor is combined with the ACE model, then it is the ADCE model. An analysis has been performed by a model-fitting analysis in the studies presuming this ADCE model, and the research below is the only study available. Taking 104 pairs of 10-year-old twins (43 MZ pairs and 61 DZ pairs) and their parents (the numbers of pairs are not equivalent to those of twins) as subjects of the study by Maes et al. (1993), genetic and environmental effects on physical fitness were investigated. For this study, physical fitness tests the subjects took were divided into five performance-related fitness variables such as the arm pull and the shuttle run, and also divided into four health-related fitness variables such as maximum oxygen intake and flexibility. The twins’ correlations regarding measurable variables were in the range of .460 to .838 for MZ and .278 to .542 for DZ. As a result of a model-fitting analysis for twins only, the AE model was adopted for many variables such as
the arm pull and the vertical jump. The hypothesis that a performance-related variable is more regulated genetically than a health-related variable did not receive much support. The next analysis is of male twins who were 22.4 year-old on average with 25 pairs of MZ and 16 pairs of DZ as study subjects, performed by Thomis et al. (1998). In this study three different types of isometric strength and angles of the arm were analyzed. The correlation of MZ was between .33 to 82, whereas that of DZ was significantly lower than MZ’s. As a result, the AE model was adopted for many indexes, and the results showed that the coefficient of determination for genetic factors was over 60%.

In the classical studies, phenotype resemblances between relatives are presumed to be due only to genetic factors, and any possibilities regarding cultural transmission and effects of common environment are eliminated. For those reasons, it has been pointed out that these facts lead to a high estimate of heritability and they might even prevent an understanding of the characteristics of phenotypes (Rice et al., 1980). For such reasons, a genetic model of the ADCE model was presumed, which is a full model that combines latent variables of common environment, and a model-fitting analysis was used in this study. The most important characteristic of this approach is that it can compare and analyze some different models, and it can estimate the effects of parameters on each latent variable in the best fitting model. Possibilities of genetic effects and a comparison between genes and environments has been the main focus in classical studies. However, using a model-fitting analysis has some advantages in calculating the heredity ratio from parents to children (effect of additive genetic factor) and the environmental effect transmitted within family members (effect of common environment). However, research investigating physical fitness variables using this analysis approach can be seen only in the studies mentioned above which were done by Maes et al. (1993) and Thomis et al. (1998), and no research on Japanese physical fitness can be found. Regarding physical fitness development, there are studies describing effects of racial factors, which means genetic characteristics, and effects of ethnic factors, which means cultural characteristics (for example, Kobayashi, 1998; Sakurai, 2002). Also, as there are studies indicating that ethnicity is a factor (Perry et al., 2002), there are possibilities to detect unique influences/effects regarding genetic and environmental aspects on Japanese physical fitness, because the heritability value depends on the size of all variance components, and any change in any variance component will affect the heritability (Falconer, 1993, pp 209–212).

The purpose of this study is to estimate the relative contribution of genetic and environmental effects on physical fitness by using a correlation analysis and a model-fitting analysis with Japanese twin data.

2. Methods

2.1. Subjects

Subjects in this study were a total of 316 children and youths, 158 pairs of twins from fifth graders in elemental school to junior high school, as shown in Table 1. A zygosity diagnosis was used for the questionnaire described later.

2.2. Variables and procedure

We contacted the principals of school in order to collect the results of twins’ physical fitness in a Japanese new physical test. The test had nine items to collect the data: grip strength, sit-ups, sit and reach and side step to determine physical fitness; and distance run, 20 meter shuttle run, 50 meter run, standing broad jump and ball throw to determine motor performance. For an analysis of this study, six items were used: grip strength (kg), whose measuring method was the same for boys and girls in every school: sit ups (number of times); sit and reach (cm); side steps (points); 50 meter run (in seconds); and standing broad jump (cm), whose measuring method was the same for boys and girls in every school. The 20 meter shuttle run was not analyzed because there was not enough data collected.

A questionnaire (Ooki et al. 1991) was used for investigating the zygosity diagnosis. Cooperation from mothers of the subjects was necessary for collecting the sheets in order to complete the research.
It was clearly stated on the sheet that cooperation was voluntary. The research began in October 2000 and was completed in March 2002.

2.3. Statistical analysis

Results of the six tests, which were grip strength, sit-ups, sit and reach, side steps, 50 meter run and standing broad jump, were converted into standardized scores according to the subjects’ grades and their sex. Next an analysis was done using random data with no relation to the birth order of the subjects. Intracorrelation was calculated to find the resemblance among twins.

For a mode-fitting analysis, as indicated in Figure 1, a phenotype (P) presumes a model that is affected by latent variables such as additive genes (A), nonadditive genes (D), common environment (C) and specific environment (E) (Neale and Cardon, 1992, pp 98-104). The twins' phenotypes are described in the following equations (1) and (2) for this model. a, d, c, and e indicate path coefficients, which show the power of the effects from factors of each latent variable.

\[
P_1 = aA_1 + dD_1 + cC + eE_1 \quad (1)
\]

\[
P_2 = aA_2 + dD_2 + cC + eE_2 \quad (2)
\]

Based on a polygene model (Neale and Cardon, 1992, pp 55-70) that states a single behavior having many genetic influences, it is presumed that a correlation for additive genes is 1.0 for MZ and 0.5 for DZ, while for nonadditive genes it is 1.0 for MZ and 0.25 for DZ. From the equal environment assumption, it can be assumed that twins’ common environment should be equal and that it leads to the equation stated above. It is presumed that there is no correlation between each latent variable and that the variance is one. It is not possible to include D in an analysis model without A because all unknown numbers of A, D, C and E cannot be calculated based only on the information that the resemblance of twins who grew up in the same family indicates. And also nonadditive genes is considered as an unexplainable genetic effect using additive genes. Also, E includes some estimated factors/errors, therefore, a model excluding it is inconceivable. For these reasons, the ACE model was set as a basic model, and the ADE, AE and CE models were set as submodels. For models that accept differences between the sexes on path coefficients: these were determined for a path coefficient; am, ad, cm and em were given for males, and af, df, cf and ef for females. The S-A CE model was set to allow differences between the sexes on the ACE model. The path coefficients a, d, c and e from each latent variable were assumed by a maximum-likelihood method during the analysis. Taking the model-fitting indexes of the \( \chi^2 \) value, GFI, and AGFI into consideration, the best fitting model with AIC as a basis was selected in the end. (Yamamoto and Ono, 1999; Toyota, 2000). AMOS 4.0 for Windows was used for these analyses.

3. Results

3.1. Descriptive statistics and correlation analysis

Table 2 shows the means and the standard deviation from the measurement record for each grade
shows the results of the correlation but the same tendency was not

<table>
<thead>
<tr>
<th>Fitness Item</th>
<th>MZ</th>
<th>DZ</th>
<th>MZF</th>
<th>DZF</th>
<th>DZO</th>
</tr>
</thead>
<tbody>
<tr>
<td>grip strength (kg)</td>
<td>0.78</td>
<td>0.49</td>
<td>0.82</td>
<td>0.74</td>
<td>0.49</td>
</tr>
<tr>
<td>sit-ups (number of times)</td>
<td>0.51</td>
<td>0.48</td>
<td>0.54</td>
<td>0.46</td>
<td>0.69</td>
</tr>
<tr>
<td>sit and reach (cm)</td>
<td>0.58</td>
<td>0.29</td>
<td>0.62</td>
<td>0.54</td>
<td>0.44</td>
</tr>
<tr>
<td>side step (points)</td>
<td>0.75</td>
<td>0.47</td>
<td>0.67</td>
<td>0.80</td>
<td>0.54</td>
</tr>
<tr>
<td>50 meter run (seconds)</td>
<td>0.57</td>
<td>0.67</td>
<td>0.74</td>
<td>0.45</td>
<td>0.71</td>
</tr>
<tr>
<td>standing broad jump (cm)</td>
<td>0.68</td>
<td>0.27</td>
<td>0.81</td>
<td>0.57</td>
<td>0.24</td>
</tr>
</tbody>
</table>

large differences observed between $r_{MZM}$ and $r_{DZF}$ for the 50 meter run and the standing broad jump, and a difference was also observed between $r_{DMM}$ and $r_{DZF}$ for sit-ups, however, there was no uniform tendency except as mentioned above. Also, $r_{DZM}$ was smaller than $r_{DMM}$ and $r_{DZF}$, but the same tendency was not observed in the other items.

and sex. 92% of this data is from Shiga Prefecture, recorded in 2000. Compared to another Shiga set of data recorded by Shiga Prefectural Committee in 2001, there are differences in some items, although not a great deal.

Table 3 shows the results of the correlation coefficient categorized by twin types. For MZ and DZ, $r_{MZ}$ (the correlation coefficient of MZ hereafter referred to as such) ranged from 0.51 to 0.78, and $r_{DZ}$ ranged from 0.27 to 0.67. For grip strength and side step, $r_{MZ}$ was significantly greater than $r_{DZ}$ (grip strength: CR=3.10, $P<.01$, side step: CR=2.82, $P<.01$), and $r_{MZ}$ was greater than half of $r_{DZ}$. From these relations it can be concluded that there are effects of additive genetic and common environmental factors. There was no significant difference observed between $r_{MZ}$ and $r_{DZ}$ for sit-ups and the 50 meter run, therefore, there is no genetic effect. For the sit and reach, $r_{MZ}=0.58$ and $r_{DZ}=0.29$ were observed, meaning there was a significant difference between those two correlations (CR=2.22, $P<.05$). Their size ratio was 2:1, therefore, the similarity of MZ was only from the influence of a genetic factor, and no influence from a common environmental factor was presumed. For the standing broad jump, $r_{MZ}$ was significantly larger than $r_{DZ}$ (CR=3.37, $P<.01$), and $r_{DZ}$ was smaller than half of $r_{MZ}$, therefore, there were effects of both additive genetic and nonadditive genetic factors. Regarding the effect by the different sexes, there were no large differences observed between $r_{DZM}$ and $r_{DZF}$ for the 50 meter run and the standing broad jump, and a difference was also observed between $r_{DMM}$ and $r_{DZF}$ for sit-ups, however, there was no uniform tendency except as mentioned above. Also, $r_{DZM}$ was smaller than $r_{DMM}$ and $r_{DZF}$, but the same tendency was not observed in the other items.

3.2. Model-fitting analysis

For a model-fitting analysis, the ADE, AE and CE models were analyzed on the basis of the ACE model. Each model with the differences of sex in path coefficients, such as the S-ACE model, was also analyzed further. As a result, the model with the lowest AIC was selected as the best fitting model. The results are shown in Table 4, indicating the best fitting model for each item measured and the coefficient of determination of each factor. The coefficient of determination for each factor is a value in which a path coefficient from each latent variable in the best fitting model to a phenotype was multiplied by itself.

The AE model was selected as the best fitting model for the grip strength and the coefficients of determination were assumed as 76.9 % for additive genetic factor and 23.1% for specific environmental factor. For sit-ups, the CE model was selected, and the coefficients of determination were 51.1% for common environmental factor and 48.9% for specific environmental factor. It was the AE model which was used for the sit and reach, and the coefficients of determination were 55.2% for additive genetic factor and 44.8% for specific environmental factor. Regarding the side step, the ACE model was selected, and additive genetic factor was 32.4%, common environmental factor 39.4%
and specific environmental factor 28.1%. For the 50 meter run, the S-CE model was chosen. The coefficients of determination for boys were 75.7% for common environmental factor and 24.4% for specific environmental factor; for girls they were 53.0% for common environmental factor and 46.9% for specific environmental factor. The AE model was used for the standing broad jump, and the ratios were 66.4% for additive genetic factor and 33.6% for specific environmental factor.

4. Discussion

A model-fitting analysis was used to estimate the relative contribution of genetic and environmental effects/influence on individual differences of physical fitness. As a result, in three physical fitness items—the grip strength, the sit and reach and the standing broad jump—the best fitting model was determined to be the AE model, and a relatively high coefficient of determination of additive genetic factor was presumed. Regarding the side step, where additive genetic, common environmental and specific environmental factors have an effect, the ACE model was selected as the best fitting model. The CE model was selected for sit-ups, and the S-CE model, in which the difference between the sexes can be observed, was selected for the 50 meter run. They were selected because there was no genetic influence.

For the grip strength and standing broad jump, the coefficients of determination for additive genetic factor were 76.9% and 66.4%, whereas those for specific environmental factor were 23.1% and 33.6%. Compared to other items, these items showed a greater effect in terms of additive genetic factor. According to research by Maes, et al. (1996), the best fitting model for arm pull is the AE model, and that for the vertical jump is the S-AE model. Their coefficients of determination for additive genetic factor were quite high. From the results of the arm pull and the vertical jump in Maes’ study and those of grip strength and the standing broad jump from this study, the required characteristics of physical fitness resemble each other in each test, and also the methods of analysis were the same and the subjects’ ages were very close to each other. Therefore, the estimated values were very similar. As for the heritability of grip strength, a range of value from 0.0 to 0.71 can be seen in Malina’s review (1986). Wolanski, et al. (1980) pointed out that the heritability of grip strength and reaction time was the highest because the heritability of some partial strength is much higher than that of an entire set of strength. He also pointed out that there was a relatively high heritability for the high jump and the long jump. Even from the data recorded in Japan, a correlation coefficient of grip strength for MZ showed 0.53 to 0.93, which was relatively high (Mizuno, 1956; Suetoshi and Minobe, 1958, Higuchi and others, 1977). As for the standing broad jump, it was 0.69 (Mizuno, 1956) and 0.75 (Suetoshi and Minobe, 1958) for MZ, which was quite high. From these results and facts, it can be concluded that, owing to the characteristics of static strength and explosive strength required for grip strength and standing broad jump, the effects of genetic factors that contribute to the individual differences are relatively strong.

The model selected for the sit and reach was the AE model, and its coefficients of determination were 55.2% for additive genetic factor and 44.8% for specific environmental factor. Bouchard et al. (1997) concluded that flexibility had greater genetic influence/effects than strength and motor tasks. Also, Malina (1986) pointed out a great genetic influence on flexibility. Wolanski et al. (1980) reported that the heritability for flexibility was 0.45 to 0.75, and a relatively high heritability could be observed between the ages of 12 to 17. On the other hand, there is a study showing that flexibility has low heritability. The research by Maes et al. (1996) used the model-fitting analysis and the ACE model, whose effect on the differences between the sexes varies. The results presumed that effects for additive genetic, common environmental and specific environmental factors were as follows: 38%, 32% and 30% for male, 50%, 42% and 8% for female. Based on the fact that the intercorrelation of 30 pairs of MZ twins and 20 pairs of DZ twins with an average age of 15 were 0.73 for MZ and 0.60 for DZ, Chatterjee and Das (1995) have judged that flexibility did not have such a strong genetic effect and it is rather the common environmental factor that influences flexibility. For the research done on Japanese, partial correlations without an age category were 0.876 for MZ and 0.351 for DZ (Suetoshi and Minobe, 1958), and the intracorrelation of the total points for the sit-and-stretch and the back stretch were 0.750 for MZM, 0.850 for MZF , 0.320 for DZM and 0.670 for DZF (Nakayama, 1987). According to the result of the model-fitting analysis in this study and other results from previous studies using the same style of analysis, it can be said that the heritability of
flexibility is moderate.

For the side step, the ACE model was selected as the best fitting model, and the effects of additive genetic, common environmental and specific environmental factors were presumed as 32.4%, 39.4% and 28.1% respectively. Results for the same task were found only in the study by Suetoshi and Minobe (1958) in which the correlation was 0.886 for MZ and was 0.531 for DZ, therefore, it can be concluded that there is a greater genetic effect. The task of side step requires agility. Looking into some research done on agility, the correlations in the burpee test showed 0.508 for MZM, 0.758 for MZF, 0.856 for DZM, 0.355 for DZF (Nakayama, 1987), 0.895 for MZM and 0.705 for MZF (Mizuno, 1956). For the task of Plate tapping by Maes et al. (1996), the coefficients of determination were 56% for additive genetic factor and 44% for specific environmental factor. Wolanski et al. (1980) pointed out that there was a high heritability for the tapping task. The above mentioned statements and the results of previous research lead to the conclusion that there is a greater genetic effect on side step, and the results of correlation analysis done in this research also correlate that. However, the result of the model-fitting analysis does not match those results.

Regarding sit-ups, the CE model was selected as the best fitting one, and the following was assumed: common environmental factor accounted for 51.1%, and specific environmental factor accounted for 48.9%. No presumed result of a similar measurable task has been found in any known research conducted previously. Prior research on leg lifts, which are similar to sit-ups, by Maes et al. (1996), stated that the AE model was the best fitting model, and additive genetic factor accounted for 69% while specific environment factor accounted for 31%. This is a very different result from that of this research. From the point of view of measuring conditions for sit-ups, sit-ups require physical fitness characteristics such as strength and endurance. For push-ups, which require similar physical fitness characteristics, the environmental effect was presumed as 59.3% (Ishidoya, 1950).

For the 50 meter run the S-CE model was selected, and the coefficients of determination were as follows: common environmental factor 75.7% and specific environmental factor 24.4% for boys, and common environmental factor 53.0% and specific environmental factor 46.9% for girls. In Malina’s research (1986) focusing on 20 to 50 meter-sprints, the heritability was 0.45 to 0.91. In Wolanski et al. (1980), the heritability for 20 and 30 meter-sprints was around 0.6 to 0.8, and for a 60 meter-sprint it was 0.3 to 0.8. Mizuno’s results (1956) showed that that correlation was 0.98 for MZM and was 0.61 for MZF, whereas the results of Suetoshi and Minobe (1958) show 0.60 for MZ and 0.96 for DZ. The results of the correlation analysis by Watanabe et al. (2000) also showed 0.61 for MZM and 0.99 for MZF. In a study by Watanabe et al., whose research objective was slightly different than from that of this study, there was a genetic effect in age-related changes for height, body weight and distance run, however, there was no genetic effect reported in age-related changes for the 50 meter run. In the study by Ishidoya (1950), the ratio of the environmental effect was reported as 58.2%.

Judging from the information above, the effect of additive genetic factor on individual differences for each characteristic is relatively strong in the physical fitness items of grip strength, standing broad jump and sit and reach. In other words, it can be stated that heritability is high. This result mostly matches the results from other research done before. Although there is a shortage of research done on side step and sit-ups, those results were compared with the results of other studies done on tasks whose fitness characteristics were very similar to side step and sit-ups. The results from those studies did not match those of this study. Regarding the result of the 50 meter run, a relatively strong genetic effect in other countries’ results has been seen, however, the result from the research on Japanese revealed rather a weak genetic effect or even no effect at all. This study supports the latter result. As seen above, there are some characteristics found in this research that resemble the characteristics found in the research done before, and vise versa, therefore, it is very difficult to reach a uniform understanding. Factors that make results which do not match prior results include differences such as race, age, sex of the subjects, the social and cultural environment the subjects live in, the number of subjects, the type of relatives (twins, siblings, parent-offspring, adopted children-adoptive parents, other pairs), the characteristics of the task, the measuring method, the method of statistical analysis and so on, and yet it is not clear which factors had the strongest effects. However, in terms of the developmental stage of the subjects of this research, they were in their late childhood to early adolescence. During this period of
time, there are some unique facts about the Japanese educational system that should be considered, such as getting ready for school entrance exams and participation in club activities. Each individual’s exercise frequency varies greatly during this time. As a result, it can be pointed out that in Japan there could be a stronger effect on fitness development based on exercise frequency, which means a greater environmental effect compared to other countries. Also, as Perry et al. (2002) pointed out, dietary habits differed from country to country and that could contribute to both gaining and losing body weight, eventually affecting physical fitness. Regarding this point, further investigation is necessary.

References


International Journal of Sport and Health Science Vol.3, 1-9, 2005


Name: Enji Okuda
Affiliation: Associate Professor, Faculty of Education, Shiga University

Address: 2-5-1 Hiratsu, Ootsu, Shiga 520-0862 Japan

Brief Biographical History:
1991- Assistant Professor, Faculty of Liberal Arts, Okayama University
1995- Assistant Professor, Faculty of Education, Shiga University
1998- Associate Professor, Faculty of Education, Shiga University

Main Works:

Membership in Learned Societies:
• The Japan Society of Physical Education, Health and Sport Sciences
• The Japanese Society of Sport Psychology