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Muscular Function and Aerobic/Anaerobic Capacity to *ACTN-3* Genetic Polymorphism of Roller Speed Skating Athletes

Jae Kyung Byeon and Sun Hee Park
Department of Physical Education, Chungbuk National University, Chungbuk, Korea

Corresponding Author: Sun Hee Park
Address: Chungdae-Ro 1, Seowon-Gu, Cheongju, Chungbuk 28644, Korea
E-mail: psh12131@gmail.com
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Abstract

The purpose of this study was to examine muscle function, anaerobic power capacity and aerobic capacity depending on α-actinin-3 (*ACTN-3*) gene polymorphism of speed roller skaters. RR, RX, and XX types were determined using polymerase chain reaction (PCR) in 29 male and 26 female elite players. Isokinetic muscular function of the knee joint for sprint and long-distance events was measured by the peak torque and the total work through left and right flexors and extensors, respectively, at 60°/s for 5 repetitions and 180°/s for 26 repetitions. Anaerobic power capacity, peak power, mean power, and fatigue index were analyzed using the Wingate measurement method over 30 seconds. Aerobic capacity, maximum oxygen consumption (VO_{2max}), maximum heart rate (HR_{peak}), and anaerobic threshold (AT) level were analyzed by using Bruce protocol of maximal treadmill test. We found that sprinters in speed roller skating have a higher RR and RX frequency, whereas long-distance skaters have a higher XX frequency. In addition, RR skaters showed better anaerobic capacity than XX skaters, whereas XX skaters showed better aerobic capacity than RR skaters. Among all *ACTN-3* gene polymorphisms, RR genotype is advantageous to sport events in which anaerobic power capacity works as a determinant of performance, while XX genotype is advantageous to sport events in which aerobic capacity is required to improve performance. Therefore, these two types of *ACTN-3* gene polymorphism maybe appropriate for forecasting speed roller skaters' aerobic and anaerobic capacity of sport performance.

Keywords: *ACTN-3* polymorphism, roller speed skaters, muscular function, aerobic, anaerobic capacity

Introduction

Many sports fields are being actively to closely examine physical characteristic and genetic factor suitable for a specific event. That is because the physical characteristic and genetic information are ideal for the personal fitness training along with the juvenile selection of players, thus having an important effect on a player's maximum athletic performance.

Recently, there are many researches on genetic studies especially in sports and it contributes to the field development (Abraham et al., 2002; Chiu, Hsieh, Yeh, & Hsieh, 2005; Collins et al., 2004; Eynon, Alves, Yamin, Sagiv, & Meckel, 2009; Frederiksen et al., 2003; Oudit, Crackower, Backx, & Penniger, 2003; Scott et al., 2010; Sonna et al., 2001; Woods et al., 2002). However, only a few have looked at the factors affecting body reaction and physical function to sports in the genetic aspect (Ann et al., 2007).

Accordingly, data is needed for training programs as well as the early discovery of elite players which is linked to improving athletic performance through clarifying the sports performance ability explained by genetic factors. This reason is that physical feature and genetic factor are becoming a critical element in judging a player's potential capacity and sports ability and in predicting athletic performance.

Candidate genes relevant to sports performance are about 20 pieces regarding to endurance, strength, and power. Of these, Angiotensin Converting Enzyme (ACE) and α-actinin-3 (*ACTN-3*) gene are considered the most relevant candidate gene for sports performance (Pérusse et al., 2002; Rankinen et al., 2002).

In particular, *ACTN-3* has XX, RX, RR types of corresponding to genotype to foresee aerobic capacity, anaerobic strength and power capacity, which are mutually exclusive phenotypes. RR and RX types, which are protein onset types, are known for its advantage in events that require power and sprint abilities. On the other hand, XX type, which shows the lack of *ACTN-3* protein expression, is more appropriate for endurable sports event (MacArthur & North, 2004; North, Yang, Wattanasirichaigoon, Mills, & Easteal, 1999; Yang et al., 2003). Recent studies have shown that players with excellent endurable sports performance ability lack in *ACTN-3* (Eynon, Oliverira, et al., 2009; Niemi & Majamaa, 2005; Santiago et al., 2008; Yang et al., 2003), while *ACTN-3* was proven to be proper for players with power (Druzhevskaya, Ahmetov, Astratenkova, & Rogozkin, 2008; Niemi & Majamaa, 2005; Papadimitriou, Papadopoulos, Kouvatsi, & Triantaphyllidis, 2008; Roth et al., 2008; Santiago et al., 2008; Yang et al., 2003). However, others have reported that the condition of *ACTN-3* was not related to sports performance ability (Ahmetov et al., 2010; Lucia et al., 2006; Saunders et al., 2007; Yang et al., 2007). Thus, mutually different opinions exist, with no clear indication on a relationship of gene with a physical fitness factor in the pertinent sports event, which potentially poses importance in athletic performance.

Meanwhile, Korea has shown excellent results in roller speed skating acquiring 3 gold medals, 2 silver medals, and 2 bronze medals as it was adopted as a regular event at "The 16th Asian Games in Guangzhou, China" in 2010, and won 13 gold medals, 10 silver medals, and 7 bronze medals even at "Yeosu World Roller Speed Skating Championship" in 2011. To understand athletic performance in roller speed skaters who are doing well at international games, research is needed to investigate how physical fitness factor, which is a player's sports performance ability phenotype, is determined by a difference in genotypes related to sports performance ability. Also, this study could present data for improving athletic performance in a sports field, for developing an excellent player's potential capability, and for a training program through clarifying the sports performance ability according to a genetic element. Therefore, the purpose of this study is to examine roller speed skaters' muscular function, aerobic and anaerobic capacity depending on *ACTN-3* genetic polymorphism. Accordingly, the major practical contribution of the findings is that it can enhance roller speed skaters' athletic performance and help form a scientific training program by presenting criteria for genomorphism according to sporting events when selecting competitors.

Methods

Subjects

The subjects in this study were players who have a game result above the 3rd place at a national competition including representative roller skaters and have been registered in Korea Roller Sports Federation, divided into short distance and long distance. All participants in current study understand all procedures and agree to attend the study. The participation subjects were chosen only those who have good physical condition and who have no muscular and neurotic disease, genetic disorder, and heart ailment. The subjects' physical characteristics are as Table 1.

Measurement Items and Methods

The genotypes of *ACTN-3*. The monocytes from blood were obtained from ethylenediamine-tetraacetic acid (EDTA) tubes for genomic

Table 1
Physical Characteristics of Subjects (*M* ± *SD*)

Group	*n*	Age (year)	Height (cm)	Weight (kg)	Body fat (%)
Male	29				
Short-distance	14	19.61 ± 2.59	175.62 ± 5.95	68.67 ± 6.59	10.36 ± 1.89
Long-distance	15	19.80 ± 2.04	174.64 ± 4.61	65.40 ± 7.24	11.06 ± 2.71
Female	26				
Short-distance	14	20.35 ± 3.17	168.07 ± 5.43	60.28 ± 4.21	21.08 ± 3.40
Long-distance	12	19.66 ± 4.03	165.46 ± 4.06	55.31 ± 3.77	21.00 ± 4.04

DNA purification by the phenol-chloroform extraction method. The *ACTN-3* gene was analyzed by polymerase chain reaction (PCR). The sense primer was 5’-CTGGAGACCACTCCC ATCCTTTCT-3’ and the antisense primer was 5’-ATGTGGC CATCACATTCGTCAGAT-3’. The XX type showed bands at 108 bp, 97 bp and 86 bp, the RX type showed 4 bands at 205 bp, 108 bp, 97 bp and 86 bp and the RR type showed 2 bands at 205 bp and 86 bp (Figure 1).

Isokinetic muscle-function test. Isokinetic muscle-function test measured muscular function using Cybex HUMAC NORM770 (Computer Sports Medicine, Inc., Stoughton, MA) equipment through making it perform flexion-extension motion in each knee joint.

To minimize unfamiliarity or discomfort, measurement was carried out after the subjects are conducted pre-exercise 3–5 times in the flexion and extension exercise focusing on the knee joint. Experimenter encouraged the subjects to carry out exercise with maximum willpower during the measurement. The measurement was conducted 5 times at 60°/s and 26 times at 180°/s. Rest in each exercise velocity was set to be 60 seconds.

The measurement contents include peak torque and total work. To gauge this, the exercise velocity was changed into 60°/s, 180°/s, respectively, thereby having measured torque in flexor and extensor on the left and right side.

Aerobic capacity test. Exercise stress test was carried out to measure aerobic capacity. On the day of testing, the subjects were explained matters related to the test. The subjects arrived at 9 o’clock in the morning, carried out stretching and warm-up after getting enough rest, listened to the description on experimental contents and procedure, and then were measured the resting heart rate.

The exercise stress test was conducted the maximal graded exercise test with Bruce Protocol using a cardiopulmonary diagnosis system of COSMED company (Rome, Italy). Blood pressure, heart rate, and self-consciousness were confirmed with an interval of every one minute during the test. At the same time, oxygen uptake during exercise was measured by analyzing the expired gas using gas analyzer with the application of the breath by breath method. The test was conducted up to the point of time that the subjects cannot continue any more, or up to the point of time that a cause for suspension takes place based on

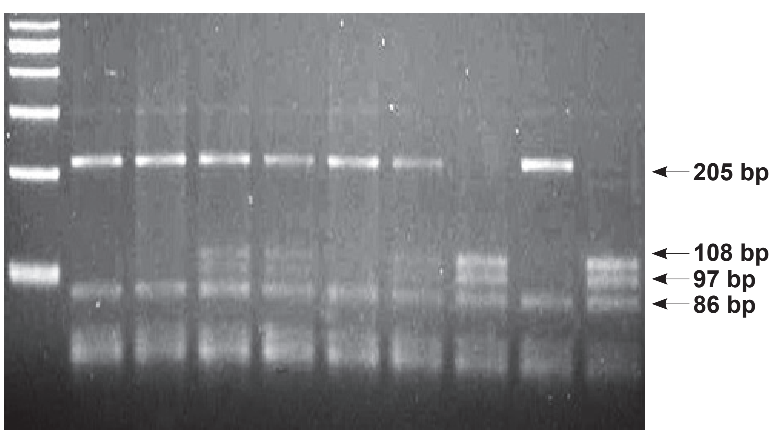

Figure 1. Restriction enzyme analysis of *ACTN-3*.

a tester's decision. Upon completion of the test, the subjects were allowed to take warm-down in the environment with 1.7 mph in one-minute velocity and 0% in degree of slope, to sit on the treadmill chair following it, to take a break for 2–3 minutes, and then were gauged heart rate and blood pressure.

The judgment of indicator during the maximum exercise was selected the greatest value out of the results, which were recorded right before or immediately after it centering on the moment with the suspension of exercise. Materials necessary for this study out of test data were divided to have been acquired.

The measurement contents were set to be maximum oxygen consumption (VO_{2max}), maximum heart rate (HR_{peak}), anaerobic threshold (AT), maximal oxygen uptake percentage (AT-%VO_{2max}).

Anaerobic capacity test. The measurement of anaerobic capacity was made by Wingate measurement method that Bar-Or (1987) reported. The measurement time of anaerobic capacity was 30 seconds and was conducted the maximal pedaling exercise by using bicycle ergometer. Relative load, which is given to an individual at this time, was set to be 0.075 kp. Thus, the relative load, which is different in load of being given to each individual, was applied.

The measurement contents were set to be peak power, mean power, and fatigue index. Peak power was set to be the power that was maximally displayed out of the power, which was shown every second in the maximal pedaling exercise for 30 seconds. Fatigue index was calculated by [(highest value-minimum value) / maximum value × 100] formula through using the maximum value and minimum value in anaerobic power, which was indicated during the maximal pedaling exercise for 30 seconds.

Data Processing

The collected data in this study were used SPSS 17.0 statistical processing program, and were summarized by calculating frequency distribution and proportion, and mean (*M*) and standard deviation (*SD*). To analyze a difference between isokinetic muscular function and aerobic/anaerobic capacity according to genotype in *ACTN-3* genetic polymorphism, Kruskal-Wallis *H* test was carried out. The level of significance was set at $p < .05$.

Results

Frequency Distribution of *ACTN-3* Genetic Polymorphism

The distribution ratio of *ACTN-3* genetic polymorphism in roller speed skaters is shown in Table 2. Male sprinters were divided into RR type with 57.1% (n = 8), RX type with 28.6% (n = 4), and XX type with 14.3% (n = 2). Long-distance players appeared to be RR type with 13.3% (n = 2), RX type with 40.0% (n = 6), and XX type with 46.7% (n = 7). Female sprinters were classified into RR type with 21.4% (n = 3), RX type with 57.2% (n = 8), and XX type with 21.4% (n = 3). Long-distance players were indicated to be RR type with 16.6% (n = 2), RX type with 41.7% (n = 5), and XX type with 41.7% (n = 5).

Muscular Function Depending on *ACTN-3* Genetic Polymorphism

Outcome of isokinetic knee-joint muscular function (60°/s). As Table 3, a significant difference was shown only in male players' right extensor at peak torque/kg ($p < .5$). RR type

Table 2
Subjects Distribution According to ACTN-3 Polymorphism

Group	*n*	Genotype (%)		
		RR	RX	XX
Male	29			
Short-distance	14	8 (57.1%)	4 (28.6%)	2 (14.3%)
Long-distance	15	2 (13.3%)	6 (40.0%)	7 (46.7%)
Female	26			
Short-distance	14	3 (21.4%)	8 (57.2%)	3 (21.4%)
Long-distance	12	2 (16.6%)	5 (41.7%)	5 (41.7%)

Table 3
Comparison in Isokinetic Muscular Function According to ACTN-3 Polymorphism (60°/s) (M ± SD)

Group	RR	RX	XX	χ^2	*p*
Male (*n* = 29)					
Peak torque (Nm)					
RE	233.80 ± 35.60	201.70 ± 35.24	198.25 ± 41.62	5.834	.054
LE	211.70 ± 39.16	199.50 ± 29.80	191.37 ± 34.07	2.110	.348
RF	142.30 ± 19.31	134.70 ± 24.78	116.75 ± 31.01	5.836	.054
LF	129.00 ± 23.17	132.60 ± 23.84	123.37 ± 20.94	1.759	.415
Peak torque (Nm/kg)					
RE	344.90 ± 45.16	304.12 ± 44.56	297.10 ± 36.74	6.571	.037*
LE	305.80 ± 51.20	293.31 ± 31.45	292.60 ± 26.56	0.472	.790
RF	210.00 ± 22.40	199.60 ± 34.57	178.37 ± 35.27	5.583	.061
LF	187.70 ± 35.54	195.10 ± 31.74	189.87 ± 19.21	1.836	.399
Female (*n* = 26)					
Peak torque (Nm)					
RE	124.60 ± 45.51	146.14 ± 23.87	150.57 ± 29.94	2.179	.336
LE	123.80 ± 31.63	139.14 ± 26.58	135.42 ± 32.90	2.096	.351
RF	110.20 ± 17.73	82.71 ± 20.91	82.28 ± 16.84	0.692	.707
LF	84.00 ± 30.92	82.64 ± 18.15	78.57 ± 13.53	0.158	.924
Peak torque (Nm/kg)					
RE	212.80 ± 63.43	250.85 ± 42.37	269.42 ± 44.63	3.050	.218
LE	210.00 ± 31.92	238.57 ± 45.18	250.00 ± 54.00	2.833	.243
RF	131.00 ± 36.92	141.64 ± 34.92	147.28 ± 26.88	0.945	.623
LF	142.40 ± 38.79	141.78 ± 30.05	140.42 ± 23.71	0.057	.972

Note. RE = right extensor; LE = left extensor; RF = right flexor; LF = left flexor.
*$p < .05$.

appeared to have a higher place than XX type. Female players were not indicated a significant difference in all variables.

Outcome of isokinetic knee-joint muscular function (180°/s). As shown in Table 4, both men and women did not show any significant difference in all variables.

Aerobic Capacity According to *ACTN-3* Genetic Polymorphism

As shown in Table 5, a significant difference was found in VO_{2max}, AT of male players ($p < .05$). Female players also showed a significant difference in VO_{2max} ($p < .05$) and AT ($p < .01$). XX type was indicated to have a higher place than RR and RX types.

Anaerobic Capacity According to *ACTN-3* Genetic Polymorphism

As shown in Table 6, RR type had a significantly higher place than XX type ($p < .05$) in peak power and mean power of male players. Female players did not show a significant difference in all variables.

Table 4

Comparison in Isokinetic Muscular Function According to ACTN-3 Polymorphism (*180°/s*) (*M* ± *SD*)

Group	RR	RX	XX	χ^2	*p*
Male (*n* = 29)					
Total work (J)					
RE	2,998.90 ± 461.80	2,734.40 ± 750.73	2,977.75 ± 540.73	0.255	.880
LE	2,893.00 ± 468.68	2,742.80 ± 440.17	2,926.62 ± 573.99	1.115	.573
RF	2,124.80 ± 182.63	1,910.10 ± 456.01	2,005.25 ± 367.56	1.333	.514
LF	2,074.00 ± 241.00	2,012.70 ± 341.51	2,075.50 ± 342.79	0.018	.991
Total work (J/kg)					
RE	4,463.30 ± 861.69	4,038.10 ± 954.10	4,567.87 ± 509.18	1.901	.387
LE	4,289.60 ± 753.69	4,037.40 ± 556.55	4,474.75 ± 461.60	2.255	.324
RF	3,162.30 ± 439.64	2,818.30 ± 630.44	3,082.00 ± 438.51	2.803	.246
LF	3,094.20 ± 551.00	2,957.60 ± 415.55	3,188.25 ± 339.38	0.625	.732
Female (*n* = 26)					
Total work (J)					
RE	1,838.80 ± 591.38	1,874.00 ± 408.95	2,182.14 ± 522.63	0.609	.737
LE	1,671.80 ± 635.21	1,726.42 ± 368.96	2,005.42 ± 380.65	0.754	.686
RF	1,307.20 ± 489.08	1,279.21 ± 334.08	1,426.14 ± 237.95	0.522	.770
LF	1,357.00 ± 442.64	1,275.35 ± 280.34	1,374.71 ± 180.49	0.558	.756
Total work (J/kg)					
RE	3,109.00 ± 788.92	3,204.35 ± 649.11	3,891.85 ± 713.84	3.338	.188
LE	2,816.20 ± 936.35	2,949.71 ± 579.66	3,579.28 ± 471.80	5.627	.060
RF	2,203.40 ± 661.30	2,185.42 ± 539.55	2,552.42 ± 331.80	1.828	.401
LF	2,287.00 ± 560.11	2,176.00 ± 427.25	2,465.71 ± 259.76	2.438	.296

Note. RE = right extensor; LE = left extensor; RF = right flexor; LF = left flexor.

Table 5

Comparison in Aerobic Capacity According to ACTN-3 Polymorphism (*M* ± *SD*)

Group	RR	RX	XX	χ^2	*p*
Male (*n* = 29)					
VO_{2max} (ml/kg/min)	58.26 ± 3.61	60.21 ± 7.93	66.74 ± 4.66	7.012	.030*
HR_{peak} (beats/min)	197.00 ± 5.18	190.90 ± 5.23	194.62 ± 5.90	5.683	.058
AT (ml/kg/min)	42.73 ± 4.74	46.97 ± 9.71	53.37 ± 5.32	7.283	.026*
AT-%VO_{2max}	74.05 + 5.46	77.59 + 6.94	79.07 + 5.07	3.115	.211
Female (*n* = 26)					
VO_{2max} (ml/kg/min)	50.51 ± 4.27	48.43 ± 4.80	58.81 ± 8.04	8.219	.016*
HR_{peak} (beats/min)	191.20 ± 5.89	189.28 ± 7.99	190.00 ± 9.41	0.322	.851
AT (ml/kg/min)	38.28 ± 4.31	35.50 ± 3.08	46.30 ± 7.31	13.200	.001**
AT-%VO_{2max}	75.88 + 7.17	73.69 + 6.63	78.65 + 4.53	2.358	.308

Note. VO_{2max} = maximum oxygen consumption; HR_{peak} = maximum heart rate; AT = anaerobic threshold; AT-%VO_{2max} = maximal oxygen uptake percentage.

$^*p < .05$, $^{**}p < .01$.

Table 6

Comparison in Anaerobic Power Capacity According to ACTN-3 Polymorphism (*M* ± *SD*)

Group	RR	RX	XX	χ^2	*p*
Male (*n* = 29)					
Peak power (W)	828.00 ± 176.00	669.43 ± 70.72	631.93 ± 96.85	7.251	.027*
Peak power (W/kg)	11.69 ± 1.69	10.23 ± 0.97	10.18 ± 0.45	5.914	.052
Mean power (W)	604.70 ± 96.42	513.87 ± 48.42	493.93 ± 73.86	7.439	.024*
Mean power (W/kg)	8.56 ± 0.72	7.85 ± 0.52	7.96 ± 0.38	5.287	.071
Fatigue index (%)	53.33 ± 4.73	48.86 ± 5.61	56.25 ± 17.31	3.990	.136
Female (*n* =26)					
Peak power (W)	411.03 ± 61.97	402.09 ± 72.30	403.84 ± 64.03	0.100	.951
Peak power (W/kg)	6.85 ± 0.77	6.75 ± 0.78	7.28 ± .74	1.351	.509
Mean power (W)	317.69 ± 40.42	307.55 ± 44.64	304.19 ± 46.18	0.863	.650
Mean power (W/kg)	5.29 ± 0.31	5.21 ± 0.41	5.49 ± 0.57	0.806	.668
Fatigue index (%)	51.41 ± 10.92	50.72 ± 10.33	44.88 ± 4.25	2.720	.257

$^*p < .05$.

Discussion

Frequency Distribution of *ACTN-3* Genetic Polymorphism

Male sprinters showed the highest frequency distribution of RR type in roller speed skaters' *ACTN-3* genetic polymorphism. Male long-distance players have shown be the highest in XX type while the female sprinters have shown the highest in RX type. The female long-distance players were shown to be higher in RX type and XX type than RR type. This outcome is showing a similar result to this study because of a report that the ratio in RR type was indicated to be high in consequence of having analyzed *ACTN-3* genotype targeting pro footballers in a research by Santiago et al. (2008), and of a report that *ACTN-3* genotype appeared to be RR type with 53%, RX type with 39%, and XX type with 8% in excellent sprint/power male players and to be RR type with 43%, RX type with 57%, and XX type with 0% in female players in a research by Yang et al. (2003). Also, even a research by Scott et al. (2010) reported that genotype was found low XX type in Jamaican and American sprinters, thereby having been able to be confirmed to be consistent with the outcome of this study. Therefore, *ACTN-3* gene could have high possibility in predicting the potential for the ability of performing anaerobic muscular ability and power exercise, and is thought to be likely capable of being usefully applied even to training for players' selecting sports and improving athletic performance.

Muscular Function According to *ACTN-3* Genetic Polymorphism

α-actinin-3, one of the actin-binding protein cluster of being manifested in *ACTN-3* gene, is revealed only in the fast twitch muscle fiber, thereby playing a role of forming stable structure and support for strong muscular contraction in fast muscle and of regulating energy metabolism and tissue differentiation (Kim & Kim, 2005). α-actinin-3 in myomere is closely related to the sports performance ability as the principal component of Z line in both ends of myomere in which actin filament is crossly linked and will play a critical role even functionally in muscular structure and function (MacArthur & North, 2004; Yang et al., 2003; Zanoteli et al., 2003). In addition, Yang et al. (2007) mentioned that the existence of α-actinin-3 is needed when the optimal muscular contraction happens at fast speed and that *ACTN-3* genetic polymorphism has impact on muscular strength, and reported that *ACTN-3* genetic polymorphism will have influence upon facilitating the formation of the fast twitch muscle fiber.

In this study, a difference among genetic polymorphisms indicated ($p < .05$) in the male players' right extensor at peak torque/kg among variables relevant to isokinetic knee-joint muscular function according to *ACTN-3* genetic polymorphism. A significant difference did not appear in other variables. But RR type and RX type showed a slightly higher tendency than XX type. In a research on *ACTN-3* and isokinetic muscular function by Shin and Kim (2010), the isokinetic muscular function and agility were reported to have a relationship with R allele, thereby having brought about a similar result to this study. However, a constant tendency was not shown in female players, thereby having appeared to be different from previous researches (Nazarov et al., 2001; Yang et al., 2003), that RR type is genotype suitable for muscle power capacity. Hence, it is thought that there will be a little difficulty in giving a significance to the contribution of *ACTN-3* genotype to muscle power capacity. Also, it may be affected by gender and sports event rather than a difference caused by *ACTN-3* genetic polymorphism, and is considered to be a result that a difference in a factor of muscle power capacity is shown by the event-based major technique display, by the continuous stimulation according to movement (training amount and intensity), and by skill level.

Aerobic Capacity According to *ACTN-3* Genetic Polymorphism

ACTN-3 gene has genotype available for predicting aerobic capacity, anaerobic muscle strength, and power capacity, which are the mutually opposing phenotype. RR type and RX type, which are *ACTN-3* protein onset types, are known for being favorable to power and sprint events. On the other hand, XX type, which shows the lack of *ACTN-3* expression, is being reported to be appropriate for endurable sports event (MacArthur & North, 2004; North et al., 1999; Yang et al., 2003).

A significant difference was indicated in VO_{2max} and AT of male players ($p < .05$) among variables related to aerobic capacity according to *ACTN-3* genetic polymorphism. XX type showed a higher tendency than RR type. In addition, even female players were indicated a significant difference in VO_{2max} ($p < .05$) and AT ($p < .01$). XX type appeared to have a higher tendency than RR type and RX type.

The outcome shows what is consistent with a research of clarifying that *ACTN-3* protein-lacking XX type gene shows a positive relationship with the sports ability in excellent endurable sportsmen (Eynon, Oliverira, et al., 2009; Niemi & Majamaa, 2005; Santiago et al., 2008; Yang et al., 2003). In a research by Park et al. (2006) that showed a relationship of *ACTN-3* genetic polymorphism according to an event-based characteristic with power endurance, XX type was reported to have shown a slightly higher tendency in an endurance event of women's representative players. Thus, it is what corresponds partially to the result of this study. XX type out of the *ACTN-3* genetic polymorphism may be supposed to be likely advantageous in the aspect of muscular efficiency or energy efficiency given the endurable exercise for a long time rather than exhibiting explosive force in a short period of time (Mills et al., 2001).

Consequentially, having compared aerobic capacity in this study, XX genotype out of the *ACTN-3* genetic polymorphism was confirmed to have indicated to be significantly higher than RR type and RX type. This is what supports the opinion in previous researches as saying that XX genotype is suitable for a gene related to endurance exercise and is what suggests that *ACTN-3* protein-lacking XX genotype may be favorable to endurable event at least.

Anaerobic Capacity According to *ACTN-3* Genetic Polymorphism

ACTN-3 gene was clarified to be expected to be a gene relevant to sports performance ability in the sports science field and to have high possibility as a gene available for foreseeing the potential of anaerobic muscular strength/power sports performance ability. Out of the *ACTN-3* genetic polymorphism, RR type or RX type, not XX type, is genotype proper for anaerobic muscular strength/power exercise of demanding the maximal force exertion (MacArthur & North, 2004; Yang et al., 2003; Zanoteli et al, 2003). In consequence of having made a comparative analysis among genetic polymorphisms in male players of this study, it could be identified that a significant difference was indicated in peak power and mean power ($p < .05$), that peak power was higher in RR type than RX type and XX type, and that mean power is higher in RR type than XX type.

This showed a similar outcome to this study because a research by Yang et al. (2007) reported that there is a significant relationship between RR type and muscular strength/sprint performance of Nigerian players in the research result of a genetic relationship between *ACTN-3* genetic polymorphism distribution and athletic performance targeting middle-distance marathon runners in East Africans (Ethiopians and Kenyans) and sprinters in West Africans (Nigerians). Also, a research of targeting totally 571 people with general people (414 persons) and excellent sportsmen (158 people) by Kim et al. (2004) is backing up the result of this study because of having reported that performing anaerobic muscular strength/power exercise may be judged to be more favorable than aerobic endurable exercise in case of being high in the distribution of RR type and RX type out of the *ACTN-3* genetic polymorphism, and is especially suitable for predicting sports performance ability even in case of South Korean players.

In the meantime, the female players were not shown a consistent tendency. Even in the outcome of a comparative analysis among genetic polymorphisms, a significant difference did not appear in all variables. This was indicated to be different from the previous researches (Nazarov et al., 2001; Kim et al., 2004; Yang et al., 2003) that RR type is genotype appropriate for anaerobic power. Thus, it is thought that there will be a little difficulty in giving a significance to the contribution of *ACTN-3* genotype to power ability. Like the previous research (Ju & Kim, 2011) of having reported that *ACTN-3* genetic polymorphism may be influenced even by many environments such as race, gender and sports event, it is thought to be a result that made a difference seen by environmental elements such as event and physical fitness in female players who participated even in this study.

Conclusions

This study analyzed and examined *ACTN-3* genetic polymorphism, muscular function, aerobic/anaerobic capacity targeting 55 excellent male and female players in order to closely examine muscular function, aerobic/anaerobic capacity according to *ACTN-3* genetic polymorphism in roller speed skaters. As a result, the following conclusions were obtained.

It can be confirmed that the frequency distribution of *ACTN-3* genetic polymorphism is high in the distribution of RR type and RX type in sprinters, and that long-distance players have a slightly higher tendency in XX type. Also, it was identified that the anaerobic capacity is higher in RR type than XX type and that the aerobic capacity is significantly higher in XX type than RR.

Accordingly, it can be judged that RR genotype out of the *ACTN-3* genetic polymorphism is advantageous for sports event in which the anaerobic power ability becomes a factor of deciding athletic performance, and that XX genotype is favorable for event of demanding the aerobic capacity exertion, and is decided to be suitable for predicting the aerobic/anaerobic sports performance ability especially in roller speed skaters.

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