Adv. Exerc. Sports Physiol., Vol.15, No.3 pp.95-100, 2009.

Changes in the Peripheral Motor Nerve Conduction Velocity and its Distribution in the Lower Limbs with Long-term Exercise

Seung ryol KIM[1], Yoshiaki NISHIHIRA[1] and Arihiro HATTA[2]

[1] *Graduate School of Comprehensive Human Sciences, University of Tsukuba*
[2] *Department of Health Pharmacy, Yokohama College of Pharmacy*

Abstract

KIM, S.-R., NISHIHIRA, Y. and HATTA, A. Changes in the Peripheral Motor Nerve Conduction Velocity and its Distribution in the Lower Limbs with Long-term Exercise. Adv. Exerc. Sports Physiol., Vol.15, No.3 pp.95-100, 2009. We changed the subjects to soccer players undergoing long-term exercise to confirm these findings in detail. The leg motor nerve conduction (MCV) and distribution of the MCV ($DMCV_{peak}$), which reflects the nerve conduction velocity of the maximum relative number of nerve fibers, were measured employing the collision method to closely re-investigate the influence of long-term exercise on the MCV. The subjects were 13 athletes (20.61±1.38 years) and 13 non-athletes (19.53±0.96 years). The athlete group consisted of active soccer players with a 10-year or longer experience of competition. The non-athlete group consisted of subjects who had never belonged to any exercise club and performed little exercise in daily activities. The MCV and $DMCV_{peak}$ of two nerves each in the upper and lower limbs were significantly faster in the athlete than in the non-athlete group, suggesting that, in addition to congenital factors, complex long-term training and the specific characteristics of individual sports act to change the MCV and $DMCV_{peak}$.

Keywords: Soccer players, Collision method, Long-term exercise, MCV and $DMCV_{peak}$

I. INTRODUCTION

Many studies on the influence of exercise, particularly, long-term exercise training, on the body have been performed, and functional improvement of the respiratory (6), circulatory (16), and skeletal muscle (13) systems were reported. Molecular- and cellular-level changes associated with adaptation to exercise have also been reported. Mitochondrial enzyme expression was enhanced by training in rats, the number of mitochondria increased as the training period prolonged (12), and long-term endurance exercise training enhanced lipolysis by catecholamine in adipocytes (11). In addition, long-term exercise training was reported to change the motor nerve conduction velocity of the peripheral nerve system (2, 17). Kim et al. (17) investigated the influences of long-term exercise training on the motor nerve conduction velocity (MCV) and distribution of the MCV ($DMCV_{peak}$) in the upper limbs of wheel-chair endurance athletes (athletes), and confirmed that the MCV and $DMCV_{peak}$ were faster in the athlete than in a non-athlete group, suggesting that, in addition to congenital (genetic) factors, complex long-term training comprised of aerobic, anaerobic, and power exercise changed the MCV and $DMCV_{peak}$. However, these were observed in athletes mainly training the upper limbs long-term. Thus, we changed the subjects to soccer players undergoing long-term exercise to confirm these findings in detail. The leg motor nerve MCV and $DMCV_{peak}$, which reflects the nerve conduction velocity of the maximum relative number of nerve fibers, were measured employing the collision method to closely re-investigate the influence of long-term exercise on the MCV.

II. METHODS

A. Subjects

The subjects were 13 athletes (20.61±1.38 years) and 13 non-athletes (19.53±0.96 years). The athlete group consisted of active soccer players with a 10-year or longer experience of competition. The non-athlete group consisted of subjects who had never belonged to any exercise club and performed little exercise in daily activities. Handedness was determined using the questionnaire of the Edinburgh Handedness Inventory (15), and all subjects were right-handed. The physical characteristics of the subjects are shown in Table 1. The objective and method of the experiment were explained to the subjects before the study, and consent to participate was obtained.

B. Procedure

After entering the experimental room, the subject rested in a sitting position for 30 minutes or longer to adapt to the room temperature (22.5-25.5 °C). Thermistor temperature probes for skin temperature measurement were

Address for correspondence: Seung ryol KIM, Graduate School of Comprehensive Human Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8574, Japan
Tel/Fax: 029-853-2607
E-mail address: kim@taiiku.tsukuba.ac.jp

then attached to the measurement sites on the bilateral forearms. An earth electrode was attached to the styloid process of the ulna. Using an Ag/AgCl dish electrode as a derivation electrode, probe electrodes were attached to the muscle belly innervated by the test nerve at about 2-cm intervals, and the reference electrode was attached to a site near the distal tendon. M waves were recorded via the innervated muscle by percutaneously stimulating the test nerve, and the MCV and $DMCV_{peak}$ were determined. The MCV and $DMCV_{peak}$ of the test nerve were measured on the dominant and non-dominant sides in a random order.

C. Measurement method

The test nerves were the median and ulnar nerves. For evoked electromyography, the little finger abductor was used for the ulnar nerve and the short abductor of the thumb for the median nerve. In the legs, the abductor of the big toe was used for the tibial nerve and the short extensor of the toes for the fibular nerve. The $DMCV_{peak}$ was measured employing Tachibana's collision method, and the measurement was initiated after the skin temperature stabilized (30.2-33.5 °C). The duration and frequency of stimulation were 0.3 msec and 1 Hz, respectively. The stimulation intensity at which the M wave amplitude reached the maximum was adopted, and a supramaximum stimulus (100-120 V) corresponding to about 120% of the maximum M-wave amplitude-inducing stimulation intensity was applied to stabilize the effect of the stimulus. Regarding the stimulation interval, 2 stimulation devices of Unique Medical Co., Ltd. and Nihon Kohden Co. (Neuropac) were simultaneously operated. M waves were recorded so as to achieve as sharp a rise as possible, and attention was paid to recording identical M waveforms evoked by stimulating 2 sites. As the distance between stimulating electrodes, the distance between the negative stimulating electrodes on the peripheral and central sides was measured.

D. Collision method

A procedure of the collision method to measure DMCV devised by Hopf (6) and changed by Tachibana (18) Collision method (by Hopf 1963): From uppermost trace to down trace, interval of two stimulation sites (S1-S2) is increased step by step. If two stimulation are given simultaneously (A), only the muscle response evoked by distal stimulation site (M1) can be recorded, for in all the motor fibers, descending impulses evoked at the proximal stimulation site collides with ascending impulses evoked at the distal stimulation site and disappear. In case of that the proximal stimulation (S2) is given when the ascending impulse evoked by distal stimulation (S1) has passed the proximal stimulation site in the fastest conducting motor fiber (B), a small muscle response corresponding to the proximal stimulation site (M2) can be recorded. Conduction velocity of the fastest motor fiber in the nerve bundle can be calculated as the distance of two stimulation sites is divided by the interval of the two stimulation. As interval is increased, muscle response corresponding to the proximal stimulation site (M2) increase its amplitude (C). M2 response becomes maximum in case of that the S2 is given when in all the fibers ascending impulses evoked by S1 has passed the proximal site (D). As mentioned above, the slowest conduction velocity in this study can be calculated. (Fig. 1)

E. Statistical analysis

The body weight was analyzed employing the unpaired t-test. The measured MCV and $DMCV_{peak}$ were subjected to two-way layout mixed ANOVA of group (athlete and non-athlete groups) x dominant side (dominant and

Table 1 Physical characteristics of subjects

	Training group (n=13)	Non-training group (n=13)
Age (years)	20.61 ± 1.38	19.53 ± 0.96
Height (cm)	173.4 ± 7.34	170.9 ± 5.73
Weight (kg)	67.89 ± 7.16**	62.19 ± 8.2
Career (years)	13.0 ± 1.53	—

Values are means ± SD.
**p < 0.01; a significant difference between training group and non-training group

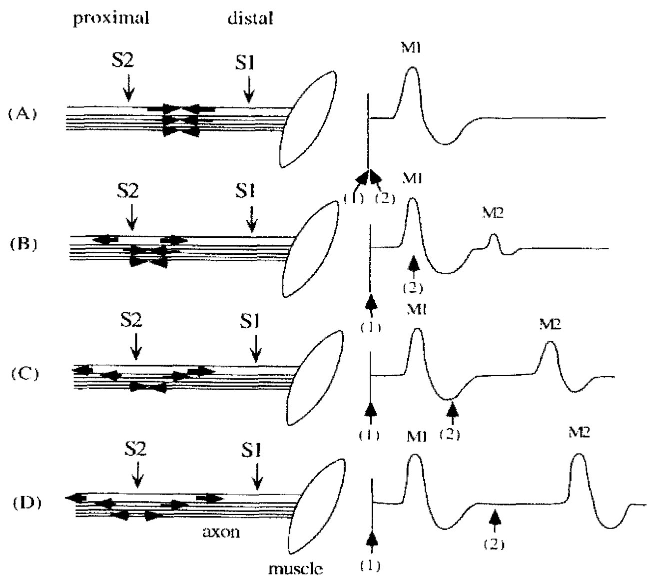


Fig. 1 A procedure of the Collision method to measure DMCV devised by Hopf and changed by Tachibana
S1: distal stimulation
S2: proximal stimulation site
M1: Muscle response evoked by distal stimulation site
M2: Muscle response evoked by proximal stimulation site

non-dominant sides). When a main effect was obtained regarding the groups, the unpaired t-test was employed, and when a main effect was obtained regarding the dominant side, the paired t-test was employed. When an interaction was detected, subsequent analysis was performed. When no Mauchly's sphericity could be assumed on ANOVA, the degree of freedom and significance level of the test were re-calculated using the Greenhouse-Geisser ε value. The significance level was set to less than 0.05.

III. RESULTS

A. Physical characteristics of the subjects

Table 1 shows the physical characteristics of the subjects. On the unpaired t-test of the body weight, the value was significantly higher in the athlete than in the non-athlete group (Table 1).

B. MCV

Table 2 shows the ulnar MCV in the athlete and non-athlete groups. On two-way mixed ANOVA of the ulnar MCV (group x dominant side), a main effect was detected in the factor of group {$F(1,24)=4.53$, $p<0.05$}. On the unpaired t-test, the MCV tended to be faster in the athlete than in the non-athlete group on the dominant ($p=0.057$) as well as non-dominant side ($p=0.085$). No interaction was noted.

Table 2 shows the median MCV in the athlete and non-athlete groups. On two-way mixed ANOVA of the median MCV (group x dominant side), no significant difference was noted in any factor.

Table 2 shows the fibular MCV in the athlete and non-athlete groups. On two-way mixed ANOVA of the fibular MCV (group x dominant side), a main effect was detected in the factor of group {$F(1, 24)=43.19$, $p<0.001$}. On the unpaired t-test, the MCV was significantly faster in the athlete than in the non-athlete group on both the dominant and non-dominant sides. No interaction was noted.

Table 2 shows the tibial MCV in the athlete and non-athlete groups. On two-way mixed ANOVA of the tibial MCV (group x dominant side), a main effect was detected in the factor of group {$F(1, 24)=21.36$, $p<0.001$}. On the unpaired t-test, the MCV was significantly faster in the athlete than in the non-athlete group on both the dominant and non-dominant sides. No interaction was noted.

C. $DMCV_{peak}$

Fig. 2 shows the ulnar $DMCV_{peak}$ in the athlete and non-athlete groups. On two-way mixed ANOVA of the ulnar $DMCV_{peak}$ (group x dominant side), a main effect was detected in the factor of group {$F(1, 24)=27.07$, $p<0.001$}. On the unpaired t-test, the MCV was significantly faster in the athlete than in the non-athlete group on both the dominant and non-dominant sides. No interaction was noted.

Fig. 3 shows the median $DMCV_{peak}$ in the athlete and non-athlete groups. On two-way mixed ANOVA of the median $DMCV_{peak}$ (group x dominant side), main effects were detected in the factors of dominant side {$F(1, 24)=6.40$, $p<0.05$} and group {$F(1, 24)=14.46$, $p<0.001$}. On the paired t-test regarding the factor of the dominant side, the $DMCV_{peak}$ was significantly faster in the dominant side than non-dominant in the both groups. On the unpaired t-test regarding the factor of group, the $DMCV_{peak}$ was significantly faster in the athlete than in the non-athlete group on both the dominant and non-dominant sides. No interaction was noted.

Fig. 4 shows the fibular $DMCV_{peak}$ in the athlete and non-athlete groups. On two-way mixed ANOVA of the fibular $DMCV_{peak}$ (group x dominant side), a main effect was detected in the factor of group {$F(1, 24)=45.90$, $p<0.001$}. On the unpaired t-test regarding the factor of group, the $DMCV_{peak}$ was significantly faster in the athlete than in the non-athlete group on both the dominant and non-dominant sides. No interaction was noted.

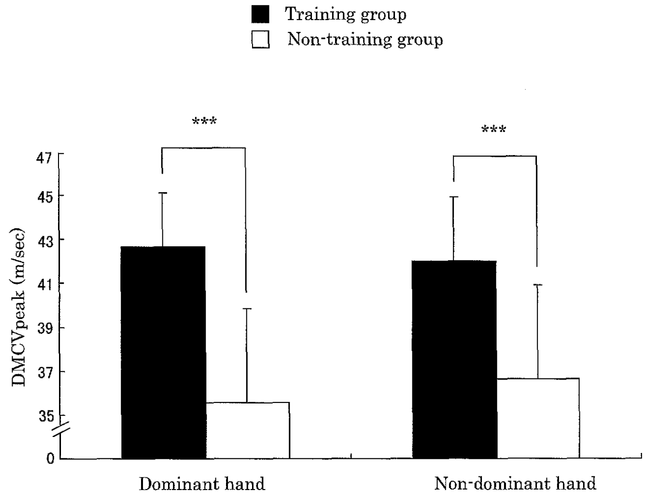
Fig. 5 shows the tibial $DMCV_{peak}$ in the athlete and non-athlete groups. On two-way mixed ANOVA of the tibial $DMCV_{peak}$ (group x dominant side), a main effect was detected in the factor of group {$F(1, 24)=7.89$, $p<0.01$}. On the unpaired t-test regarding the factor of group, the

Table 2 Comparison of MCV in athlete and non-athlete

Membrum superius	Ulnar nerve		Median nerve	
	Dominant	Non-Dominant	Dominant	Non-Dominant
Training group (n = 13)	58.19 ± 1.89	57.73 ± 2.27	58.28 ± 2.48	56.70 ± 2.81
Non-training group (n=13)	55.48 ± 2.38	55.04 ± 2.80	57.45 ± 2.22	56.12 ± 3.22
Membrum inferius	**Peroneal nerve**		**Tibial nerve**	
	Dominant	Non-Dominant	Dominant	Non-Dominant
Training group (n=13)	49.99 ± 0.34**	49.21 ± 0.61**	49.17 ± 0.64**	48.69 ± 0.66**
Non-training group (n=13)	45.94 ± 0.51	44.9 ± 0.81	44.34 ± 0.8	44.11 ± 1.07

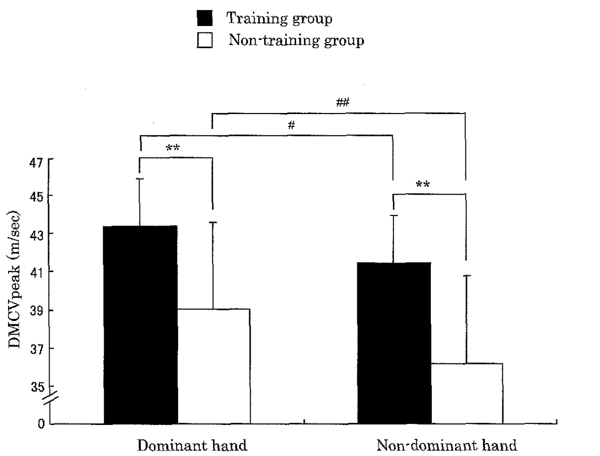
Values are means ± SE

**p < 0.01; a significant difference between training group and non-training group



Values are means ± SE.
***p < 0.001; a significant difference between training and non-training group.

Fig. 2 Fig. 2 shows the ulnar $DMCV_{peak}$ in the athlete and non-athlete groups. On two-way mixed ANOVA of the ulnar $DMCV_{peak}$ (group x dominant side), a main effect was detected in the factor of group {$F(1, 24)=27.07$, $p<0.001$}. On the unpaired t-test, the MCV was significantly faster in the athlete than in the non-athlete group on both the dominant and non-dominant sides. No interaction was noted.



Values are means ± SE.
**p < 0.01; a significant difference between training and non-training group.
#p < 0.05; a significant differencebetween the dominant and non-dominant hands in the training group. ##p < 0.01; a significant difference between the dominant and non-dominant hands in the non-training group.

Fig. 3 Fig. 3 shows the median $DMCV_{peak}$ in the athlete and non-athlete groups. On two-way mixed ANOVA of the median $DMCV_{peak}$ (group x dominant side), main effects were detected in the factors of dominant side {$F(1, 24)=6.40$, $p<0.05$} and group {$F(1, 24)=14.46$, $p<0.001$}. On the paired t-test regarding the factor of the dominant side, the $DMCV_{peak}$ was significantly faster in the athlete than in the dominant side than non-dominant in the both groups. On the unpaired t-test regarding the factor of group, the $DMCV_{peak}$ was significantly faster in the athlete than in the non-athlete group on both the dominant and non-dominant sides. No interaction was noted.

$DMCV_{peak}$ was significantly faster in the athlete than in the non-athlete group on both the dominant and non-dominant sides. No interaction was noted.

IV. DISCUSSION

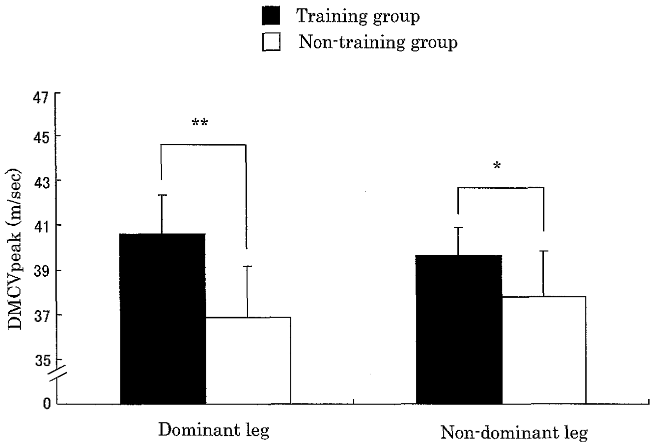
In our preceding study, the MCV and $DMCV_{peak}$, reflecting the nerve conduction velocity of the maximum relative number of nerve fibers, were measured employing the collision method in subjects with experience of long-term exercise training, and the influence of such long-term exercise training on the upper limb peripheral motor nerve conduction velocity was investigated. The MCV and $DMCV_{peak}$ were faster in the athlete (wheelchair endurance athletes) than in the non-athlete group, suggesting that, in addition to congenital (genetic) factors (9), complex long-term training comprised of aerobic, anaerobic, and power exercise changed the MCV and $DMCV_{peak}$.

To more closely confirm these findings, we measured the MCV and $DMCV_{peak}$, reflecting the nerve conduction velocity of the maximum relative number of nerve fibers employing the collision method, and re-investigated the influence of long-term exercise on the motor nerve conduction velocity and distribution.

No significant differences were noted in the ulnar or median MCV in the upper limbs on the dominant or non-dominant side between the athlete and non-athlete groups (Table 2). However, the $DMCV_{peak}$ findings indicated that the relative number of nerve fibers was greater in the regions in which the conduction velocity was faster in the athlete than in the non-athlete group in both nerves bilaterally (Fig 2 and 3). In addition, the fibular and tibial MCV were significantly faster in the athlete group bilaterally (Table 2), and the $DMCV_{peak}$ was also faster in both the fibular and tibial nerves, showing that the relative number of nerve fibers was greater in the regions in which the conduction velocity was faster in the athlete than in the non-athlete group (Fig 4 and 5).

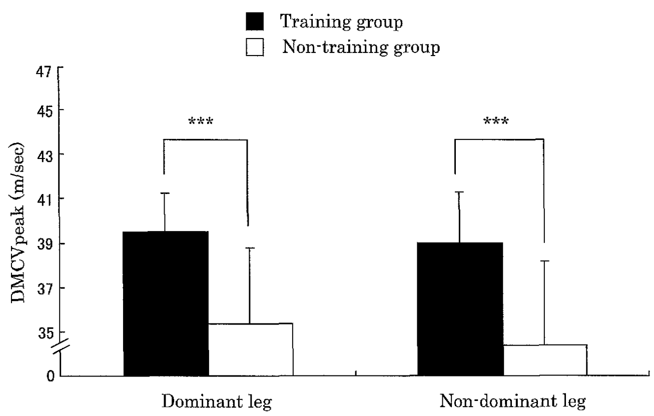
The characteristics of soccer players may be represented well by these findings. Unlike in other ball games, soccer players (excluding goal keepers) do not use their hands. Players become able to accurately handle the ball at a high speed without using their hands after considerable training. Accordingly, muscle strength, endurance, speed, and power are 4 main physical attributes generally considered necessary for soccer. Although soccer players do not use their hands or arms to touch the ball or other players, the hands and arms play an important role in all movements, such as running, stopping, balancing, kicking, and jumping.

Singh and Maini (20) compared the fibular and tibial MCV of the legs between 38 rickshaw men and 25 general healthy adults, and found that the fibular MCV was significantly faster in the rickshaw men. Park (7) compared ulnar and median MCV in the upper limb and tibial and fibular



Values are means ± SE.
**$p < 0.01$; a significant difference between training and non-training group in the dominant leg. *$p < 0.05$; a significant difference between training and non-training group in the Non-dominant leg.

Fig. 4 Fig. 4 shows the fibular $DMCV_{peak}$ in the athlete and non-athlete groups. On two-way mixed ANOVA of the fibular $DMCV_{peak}$ (group x dominant side), a main effect was detected in the factor of group {$F(1, 24)=45.90$, $p<0.001$}. On the unpaired t-test regarding the factor of group, the $DMCV_{peak}$ was significantly faster in the athlete than in the non-athlete group on both the dominant and non-dominant sides. No interaction was noted.



Values are means ± SE.
***$p < 0.001$; a significant difference between training and non-training group.

Fig. 5 Fig. 5 shows the tibial $DMCV_{peak}$ in the athlete and non-athlete groups. On two-way mixed ANOVA of the tibial $DMCV_{peak}$ (group x dominant side), a main effect was detected in the factor of group {$F(1, 24)=7.89$, $p<0.01$}. On the unpaired t-test regarding the factor of group, the $DMCV_{peak}$ was significantly faster in the athlete than in the non-athlete group on both the dominant and non-dominant sides. No interaction was noted.

MCV in the lower limb between soccer players and gymnasts. In the upper limb nerves, the MCV was faster in the gymnasts bilaterally, while the MCV of the lower limb nerves tended to be bilaterally faster in the soccer players. The MCV was faster in body regions mainly used in the sport than in those not used, suggesting that the MCV may affect sports training. Hatta et al. (2) reported similar study results. They compared athletes (trained in kendo) and general healthy adults. They observed that the ulnar MCV was significantly faster on not only the dominant but also non-dominant side, and considered that the sporting characteristics of kendo may be closely involved. They discussed the fact that the dominant side is consistently used in racket sports, such as badminton, whereas not only the dominant but also non-dominant side plays an important role in kendo because a bamboo sword is held with both hands. The sporting characteristics may have also influenced our findings. Although soccer players mainly use their lower limbs, the peak relative number of nerve fibers in the upper limb ($DMCV_{peak}$) was detected in the region in which the conduction velocity was significantly faster in the athletes than in the non-athletes (Fig 2 and 3).

Although they do not use their hands or arms to touch the ball or other players, the hands and arms play an important role in all movements, such as running, stopping, balancing, kicking, and jumping. Thus, their upper limbs are trained as well as the lower limbs, although they do not directly use them in games. It has been reported that the MCV and $DMCV_{peak}$ were significantly faster in subjects who had experience of long-term exercise training (I.e., athletes) (2, 7, 8, 10, 17). The conduction velocity of nerves is influenced by the axon diameter, and the conduction velocity becomes faster as the diameter increases. A greater electric current flows because the axon resistance is small, which shortens the time required to excite the adjacent segment (14). Arbuthnott et al. (1) and Waxman (21) reported that morphological changes in the axon diameter simultaneously change the MCV. Edds (4) confirmed in an animal study that the axon diameter increased with training in peripheral nerves, showing that training increased the nerve fiber thickness. Furthermore, Shokouhi et al. (19) recently reported that the lipoperoxide level in the sciatic nerve and Schwann cell apoptosis were reduced and the myelin sheath was thickened in treadmill exercise-loaded rats (9 and 12 months) compared to those in control rats. Bengtsson et al. (3) also reported that skillful finger movement increases the number of nerve fibers distributing from the cerebral motor area toward the spinal cord in pianists who have practiced piano since childhood. An increased number of structures, called medullary sheath of nerve cells, indicate that nerve fibers covered with an insulator rapidly send electrical impulses along the nerve fibers by saltatory conduction.

The findings including the greater MCV and $DMCV_{peak}$ values in the athlete than in the non-athlete group suggested that not only the legs but also the hands and arms play an important role in all movements of soccer, such as running, stopping, and balancing, resulting from training of the upper as well as lower limbs. As described above, the MCV and $DMCV_{peak}$ values of the two nerves in the upper limbs as well as two nerves in the lower limbs were significantly greater in the athlete than in the non-athlete group, suggesting that, in addition to congenital factors, complex long-term training and the specific characteristics of individual sports act to change the MCV and $DMCV_{peak}$.

V. CONCLUSION

The MCV of nerves in the lower limbs and $DMCV_{peak}$, reflecting the nerve conduction velocity of the maximum relative number of nerve fibers, were measured employing the collision method in soccer players performing long-term exercise, and we investigated the influence of long-term exercise on the MCV.

The MCV and $DMCV_{peak}$ of two nerves each in the upper and lower limbs were significantly faster in the athlete than in the non-athlete group, suggesting that, in addition to congenital factors, complex long-term training and the specific characteristics of individual sports act to change the MCV and $DMCV_{peak}$.

References

1) Arbuthnott E R Boyd, I A and Kalu K U (1980) Ultrastructural dimension of myelinated peripheral nerve fibers in the cat and their relation to conduction velocity. J Physiol 308: 125-157
2) Hatta A, Nishihira Y, Takemiya T, Shimoda M and Changming L (1995) Ulnar nerve conduction velocity in athletes. J Exerc Sports Physiol 2: 177-184 (in Japanese with English abstract)
3) Bengtsson S L, Nagy Z, Skare S, Forsman L, Forssberg H,Ullēn F (2005) Extensive piano practicing has regionally specific effects on white matter development. Nat Neurosci 8: 1148-1150
4) Edds M V (1950) Hypertrophy of nerve fibers to functionally overloaded muscles. J Comp Neurol 93: 259-275
5) Hopf H C (1963) Electromyographic study on so-called mononeuritis. Arch Neurol 9: 307-312
6) Jones A M and Carter H (2000) The effect of endurance training on parameters of aerobic fitness. Sports Med 29: 373-386
7) Park J H (1991) The influence physical training on distribution of peripheral motor nerve conduction velocity. Jpn J Sports Sci 10: 155-161 (in Japanese with English abstract)
8) Kamen G, Taylor P and Beehler P J (1984) Ulnar and posterior tibial nerve conduction velocity in athletes. Int J Sports Med 5: 26-30
9) Komi P V, Klissouras V and karvinen E (1973) Genetic variation in neuromuscular performance. Int Z Angew Physiol 31: 289-304
10) Lastovka M (1969) The conduction velocity of the peripheral motor nerve fibres and physical training. Act Nerv Super (praha) 11: 308
11) Martin W H 3rd (1996) Effects of acute and chronic exercise on fat metabolism. Exerc Sport Sci Rev 24: 203-232
12) Murakami T, Shimomura Y, Fujitsuka N, Nakai N, Sugiyama S, Ozawa T, Sokabe M, Horai S, Tokuyama K and Suzuki M (1994) Enzymatic and genetic adaption of soleus muscle mitocondria to physical training in rats. Am J Physiol 267: E388-E395
13) Narici M V, Hoppeler H, Kayser B, Landoni L, Claassen H, Gavardi C, Conti M and Cerretelli P (1996) Human quadriceps cross-sectional area, torque and neural activation during 6 months strength training. Acta Physiol Scand 157: 175-186
14) Norris A H, Shock N W and Wagman I H (1953) Age change in the maximum conduction velocity of motor fibers of human ulnar nerve. J Appl Physiol 5: 589-593
15) Oldfield R C (1971) The assessment and analysis of handedness: The Edinburgh inventory. Neuropsychologia 9: 97-113
16) O'Sullivan S E and Bell C (2000) The effects of exercise and training on human cardiovascular reflex control. J Auton Nerv Syst. 81: 16-24
17) Kim S R, Nishihira Y, Higashiura T, Hatta A, Hayashi Y, Hayashi Y, Kuroiwa K and Kim B J (2009) The effects of long-term exercise training on the motor nerve conduction velocity (MCV) in long-distance wheelchair athletes. J Exerc Sports Physiol 16: 17-24 (in Japanese with English abstract)
18) Tachibana S (1987) Distribution of motor nerve conduction velocities. Clin Electroencephalogr 29: 710-714 (in Japanese with English abstract)
19) Shokouhi G, Tubbs R, Shoja M Roshangar L, Mesgari M, Ghorbanihaghjo A, Ahmadi N, Sheikhzadeh F and Rad J (2008) The effects of aerobic exercise training on the age-related lipid peroxidation, Schwann cell apoptosis and ultrastructural changes in the sciatic nerve of rats. Life Sci 82: 840-846
20) Singh P I and Maini B K (1980) The influence of muscle use on conduction velocity of motor nerve fibers. Ind J physiol pharmacol 24: 65-67
21) Waxman S G (1980) Determinants of conduction velocity in myelinated nerve fibers. Muscle & Nerve 3: 141-150

(Received 20 June 2009, and in revised form 2 October 2009, accepted 26 October 2009)