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Effect of linear polarized near-infrared light irradiation on flexibility of shoulder and ankle joints

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Background. **There is a possibility that heat stimulus by linear polarized near-infrared light irradiation (PL: Super Lizer HA-30, Tokyo Medical Laboratory) improves the range of joint motion, because the flexibility of soft-part tissues, such as a muscle or a tendon, is improved by increasing the muscle temperature. The purpose of this study was to examine the influence of PL-irradiation on the ranges of shoulder and ankle motions.**

Methods. **Experimental design: 30 healthy young adults (15 males: mean±SD, age 19.1±0.8 yrs, height 173.3±4.6 cm, body mass 68.5±8.0 kg and 15 females: mean±SD, age 19.2±0.7 yrs, height 162.3±4.5 cm, body mass 58.1±6.6 kg) participated in the experiment under PL-irradiation and no-irradiation (placebo) conditions. Measures: the angles of shoulder and ankle joint motions were measured twice, before and after the PL- and placebo-irradiations. The angle of a motion was defined as the angle connecting 3 points at linearity as follows: for the shoulder, the greater trochanter, acromion, and caput ulnare, and for the ankle, the knee joint, fassa of lateral malleolus and metacarpal bone. Each angle was measured when a subject extended or flexed maximally without support.**

Results. **The trial-to-trial reliability of each range of joint motion was very high. All parameters in PL-irradiation were significantly larger in postirradiation than pre-irradiation, and the value of postirradiation in PL-irradiation was significantly greater than that for placebo. The ranges of shoulder and ankle motions in placebo-irradiation were also significantly greater in postirradiation than pre-irradiation. Moreover, the change rate for each range of joint motion between pre- and postirradiations was significantly greater in PL-irradiation in both joints. In PL-irradiation, most subject's motions were greater in postirradiation than pre-irradiation, but not in the placebo-irradiation. The effect of PL-irradiation tended to be greater on subjects with a small range of a joint motion.**

Conclusions. **It is considered from the present results that the ranges of shoulder and ankle motions became greater with PL-irradiation, and is effective as a warming-up method.**

Key words: Shoulder joint, physiology - Ankle joint, physiology - Exercise.

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Warming-up is very important to improve performance during exercise or to reduce muscle burden by exercise stress.[1-3] Although various warming-up methods are proposed, they generally aim to increase the body or muscle temperature by jogging and light exercise, and to stretch muscles by stretching.[4] Sthenia of primary metabolism and an improvement in flexibility with an increase of body and muscle temperatures, an improvement of transmission speed of nerve impulse by sthenia of nerve action, or preventing injury by inhibiting myotatic reflex, and so on, are given as physiological effects of warming-up.[1]

Flexibility is evaluated by the range of joint motion. A person with high flexibility can voluntarily show a large range of joint motion. The structure of a joint, the connective tissues surrounding muscles and bone, and soft-part tissues such as tendons, ligaments, fascia,

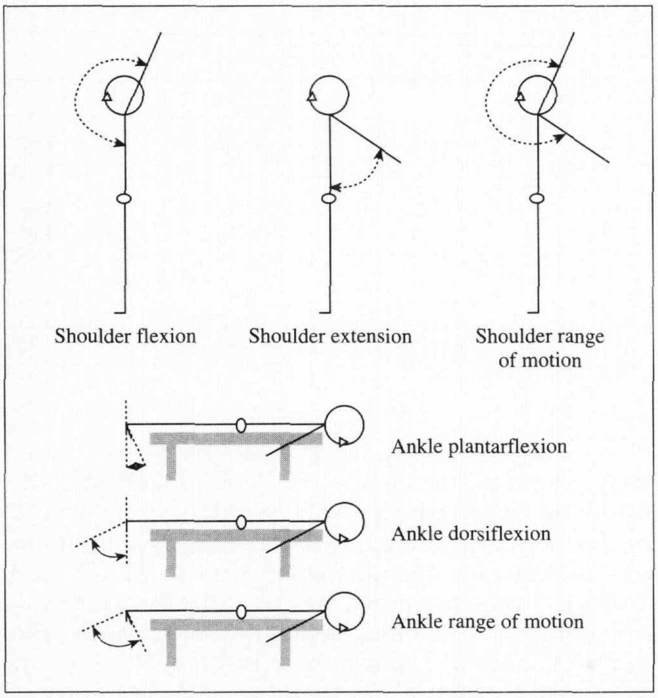

Fig. 1.—Schematic representation of the measurement method for each range of motion.

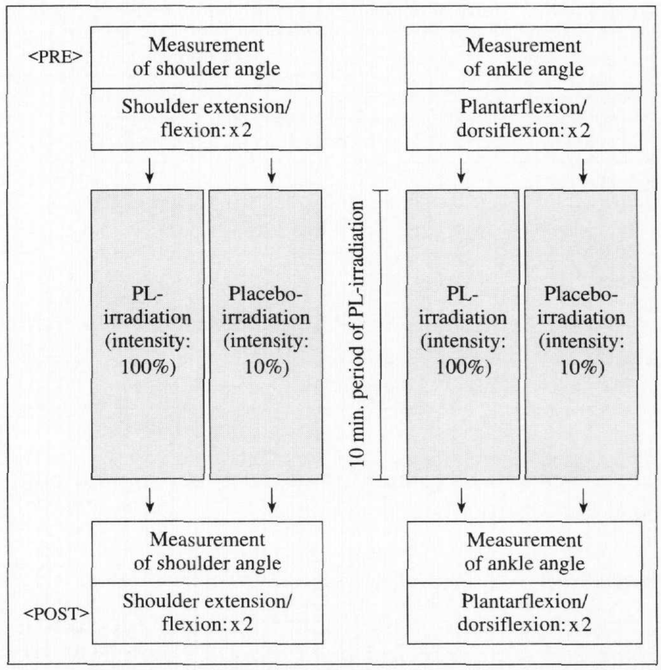

Fig. 2.—Experimental procedure. All subjects participated in both conditions (cross over design). Measurement of PL- and placebo-irradiations on the same day was avoided, considering the influence of the irradiation.

joint capsules, and skin can be given as factors in the limit of the range of joint motion.[2] The structure of a joint depends mainly on congenital influences and can be little changed by warming-up. The connective tissues surrounding muscles and born have an important role in maintaining the stability of a joint, and excessive stretching must be avoided. On the other hand, it is expected that the resilience of soft-part tissues improves by increasing the muscle temperature. Tissues resistive to muscle stretching in the soft-part tissues are the fascia, the contractile component, and the tendon.[3] Although warming-up, generally, has focused on stretching, it should include running or light exercise as well to enhance the body or muscle temperature, because the resilience of muscles is improved by warming the related tissues.

Recently, many researchers reported that linear polarized near-infrared light (PL) irradiation to muscles or meridian points gives thermal sensory or stimulation sensory.[5-7] The irradiation device was primarily developed for a therapeutic effect to analgesic or resolution in clinical settings, and, physiologically, it has been reported that an increase of blood flow or skin temperature occurs.[7-10] We considered that this device, since it is simple to operate, might be useful as support to improve the range of joint motion from the physiological effects by PL-irradiation.

The purpose of this study was to examine the influence of PL-irradiation on the ranges of shoulder and ankle motions.

Materials and methods

Subjects

Subjects were 15 males (mean±SD; age 19.1±0.8 yrs, height 173.3±4.6 cm, body mass 68.5±8.0 kg) and 15 females (mean±SD; age 19.2±0.7 yrs, height 162.3±4.5 cm, body mass 58.1±6.6 kg).

All subjects were healthy with no shoulder and ankle joint abnormalities, and regularly participated in recreational sports (more than 2 days per week). Their physical characteristics approximated the standard values for Japanese males of the same age range.[11] Written informed consent was obtained from all sub-

TABLE I.—*Reliability of the ranges of joint motion between 2 trials before PL/placebo irradiation.*

Joint motions	PL irradiation (100%)			Placebo irradiation (10%)		
	Trial 1 (mean±SD)	Trial 2 (mean±SD)	ICC	Trial 1 (mean±SD)	Trial 2 (mean±SD)	ICC
Shoulder						
—Flexion	192.9±7.1	193.6±6.7	0.96	194.6±7.9	194.9±7.2	0.98
—Extension	66.8±15.3	66.7±14.5	0.99	66.8±12.1	66.9±11.7	0.98
—Range	259.8±17.8	260.3±17.2	0.99	261.4±16.7	261.8±15.4	0.98
Ankle						
—Plantarflexion	77.7±5.9	77.2±6.0	0.97	76.3±6.0	76.0±6.3	0.98
—Dorsiflexion	-7.2±6	-7.4±6.1	0.98	-6.5±5.1	-6.1±5.2	0.93
—Range	70.5±7.8	70.0±8.6	0.98	69.8±7.6	69.9±8.1	0.97

There was no significant difference between trials at any motion.

jects after a full explanation of the experimental purpose and protocol.

Materials

The PL-irradiation used spot irradiation type linear polarized near-infrared light (Super Lizer HA-30, Tokyo Medical Laboratory, output power 1800 W, focus radius 10 mm, wavelength band 0.6 7 ì m-1.6 ì m). The irradiation unit was the type that can stimulate 1 point on the skin.

The parameters of range of joint motion

The angles of shoulder flexion and extension, and of ankle plantarflexion and dorsiflexion were measured for all subjects. The angles of shoulder and ankle motions were defined as the angle linearly connecting the following 3 points: greater trochanter, acromion, and caput ulnare, and knee joint, fassa of lateral malleolus and metacarpal bone (Figure 1). The soulder joint angle was measured with a standing posture with the subject's head, hips, and heels touching the wall.

The ankle joint angle was measured with the subject lying on the table and stretching the ankle.

Each angle was measured when the subject extended or flexed maximally without support (Figure 1).

Experimental design and procedure

The experimental design set both measurement conditions of PL- and placebo-irradiations in each range of joint motion, and was a cross over design in which all subjects participated in both conditions. The measurement of PL- and placebo-irradiations on the same day was avoided, considering the influence of the irradiation. The measurement was carried out during from 13:00 to 17:00, and subjects were instructed not to exercise on measurement days. The measurement order for each subject was done at random to eliminate the bias of order. The double blind method was used considering the psychological effect on a tester and the subjects. Figure 2 shows the experimental procedure in this study. Before PL- and placebo-irradiations, the angle of a joint motion was measured twice. The intensity in PL- and placebo-irradiations was maximal (100%) and very light (10%), respectively. The irradiation points of shoulder joints were 10 points on the trapezius and latissimus dorsi muscles, namely 5 points on the side from the 7th cervical vertebrae to the 12th thoracic vertebrae and five points on a scapula. The irradiation points of ankle joints were 4 points on the superior extensor retinaculum, inferior extensor retinaculum, extensor hallucis longus, and tendon Achillis. Before the irradiation, the irradiation points were checked by palpation, and were marked. Both irradiations were carried out for 10 min with a rotation for irradiation points using a cycle of 5 sec irradiation and 1 sec rest. Within 1 min after the irradiation, the range of motion was measured again.

Data analysis

To examine the reliability of each measurement value, the intra-class correlation (ICC) between 2 trials done before PL- and placebo-irradiations was calculated. To examine the effect of the range of joint

TABELLA II.—*Results of 2 way ANOVA for repeated measures on 2 variables.*

Parameters	Irradiation	Before and after irradiation		Two way ANOVA (F-value)			Posthoc (Tukey's HSD)			
		Pre	Post				Fa1		Fa2	
		(mean±SD)	(mean±SD)	Fa1	Fa2	IN	PL	Placebo	Pre	Post
Shoulder										
—Flexion	PL	193.9±6.8	199.9±7.3	7.44*	109.79*	61.90*	Pre<post			PL>placebo
	Placebo	194.3±7.6	195.5±7.2							
—Extension	PL	67.5±15.0	73.0±13.1	4.63*	45.36*	20.28*	Pre<post			PL>placebo
	Placebo	66.3±11.8	67.8±11.0							
—Range	PL	261.4±17.6	272.9±16.1	12.48*	115.90*	60.22*	Pre<post	Pre<post		PL>placebo
	Placebo	260.5±16.0	263.3±14.9							
Ankle										
—Plantarflexion	PL	77.1±5.9	82.2±5.9	8.30*	127.75*	35.56*	Pre<post			PL>placebo
	Placebo	76.6±6.1	77.7±5.5							
—Dorsiflexion	PL	-6.8±6.2	-2.7±5.6	2.09^{ns}	50.21*	31.87*	Pre<post			PL>placebo
	Placebo	-6.9±5.2	-6.0±5.6							
—Range	PL	70.3±8.1	79.6±8.3	12.87*	123.81*	69.51*	Pre<post	Pre<post		PL>placebo
	Placebo	69.7±7.8	71.8±8.4							

Pre/post: before and after irradiation in PL and placebo; ^{ns}: no significant difference; *: $p<0.05$; Fa1: main factor of PL and placebo irradiation; Fa2: main factor of before and after irradiation (PL and placebo); IN: interaction factor.

motion by PL-irradiation, 2 way analysis of variance (ANOVA), (PL and placebo × pre- and postirradiation) for repeated measures on 2 variables was calculated. Multiple comparisons used Tukey's HSD method. Moreover, the difference of the change rate in pre- and postirradiations for the range of joint motion was examined using a paired "t"-test. The probability level of 0.05 was considered as an indicative of statistical significance.

Results

Reliability of the range of a joint motion

Table I shows the intra-class correlation coefficients (ICC) of the ranges of joint motions between 2 trials before the PL and placebo irradiations, respectively. The ICCs were a significantly high, >0.90 for all parameters. There were no significant differences between trials in any parameter. Therefore, the reliability of these measured values was considered to be very high. The mean value of 2 trials was used for further analysis.

The effect of PL-irradiation for the range of shoulder and ankle motions

Table II shows the results of 2 way ANOVA and multiple comparisons for each parameter. Significant interaction factors were found in all parameters (Table II). In the results of multiple comparisons, all parameters in PL-irradiation were significantly greater in postirradiation than pre-irradiation, and the value of postirradiation was significantly greater in PL-irradiation than placebo-irradiation. The range of shoulder and ankle motions in placebo irradiation was significantly greater in postirradiation.

Figures 3A and B are the scatter diagrams for the ranges of shoulder and ankle motions (x-axis: pre-irradiation, y-axis: postirradiation), respectively. In PL-irradiation, most subject's motions were greater in postirradiation than pre-irradiation, whereas in placebo-irradiation, most subject's motions almost agreed in pre- and postirradiations. Moreover, the effect of PL-irradiation tended to be greater in subjects with a small range of a joint motion.

Table III shows a comparison of the results of PL- and placebo-irradiations for the change rate of each range of motion between pre- and postirradiations. There were significant differences in the ranges of joint motions, being greater in PL-irradiation.

Discussion

The main aim of warming-up is to avoid injuries, such as a pulled muscles and sprains, but it is also done to improve peak flexibility and ensure a high range of joint motion. Generally, it has focused on improving flexibility by stretching, but it is also nec-

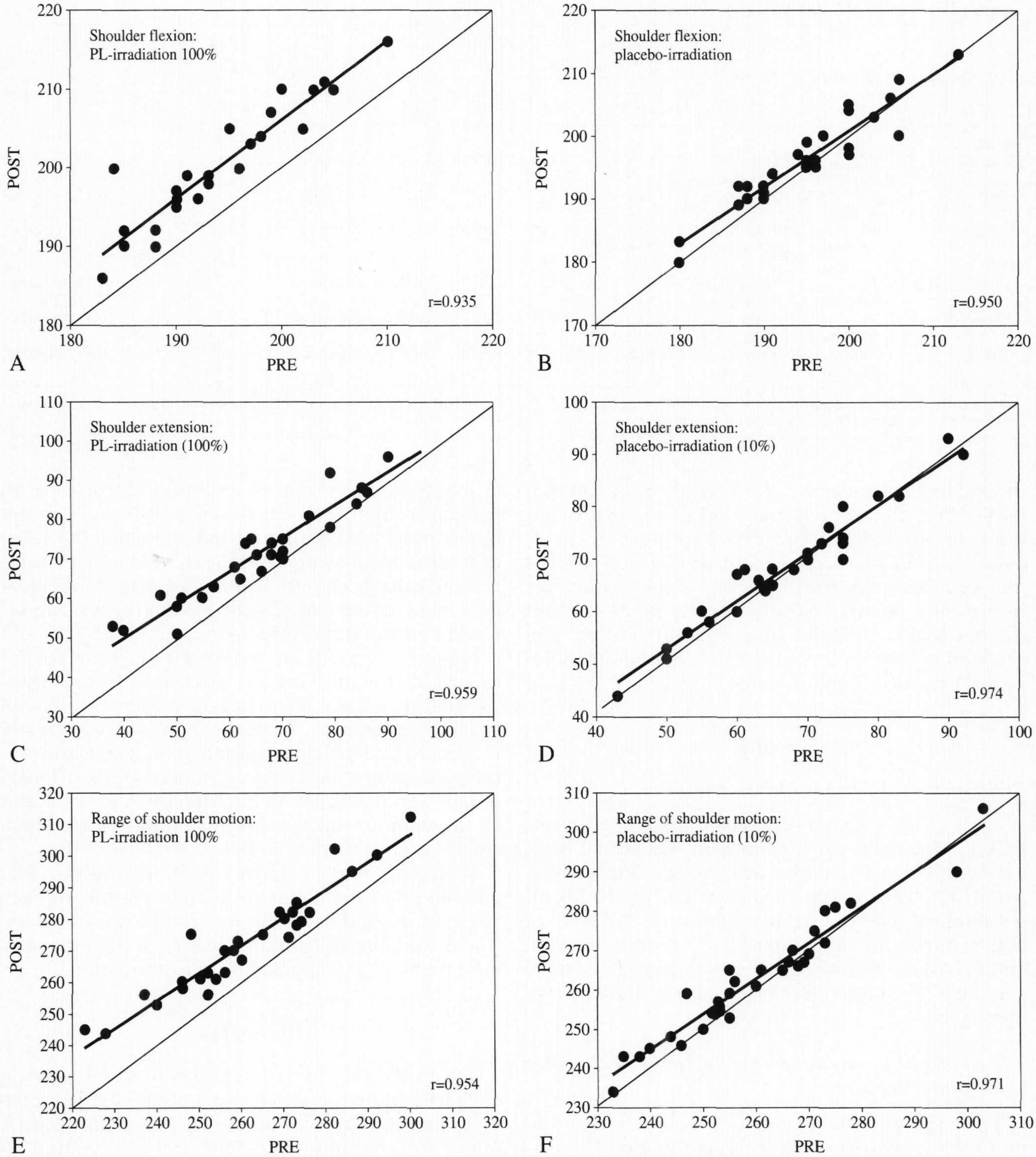

Fig. 3.—A-F) Scatter diagram for the range of shoulder motion. x-axis: pre-irradiation, y-axis: postirradiation.

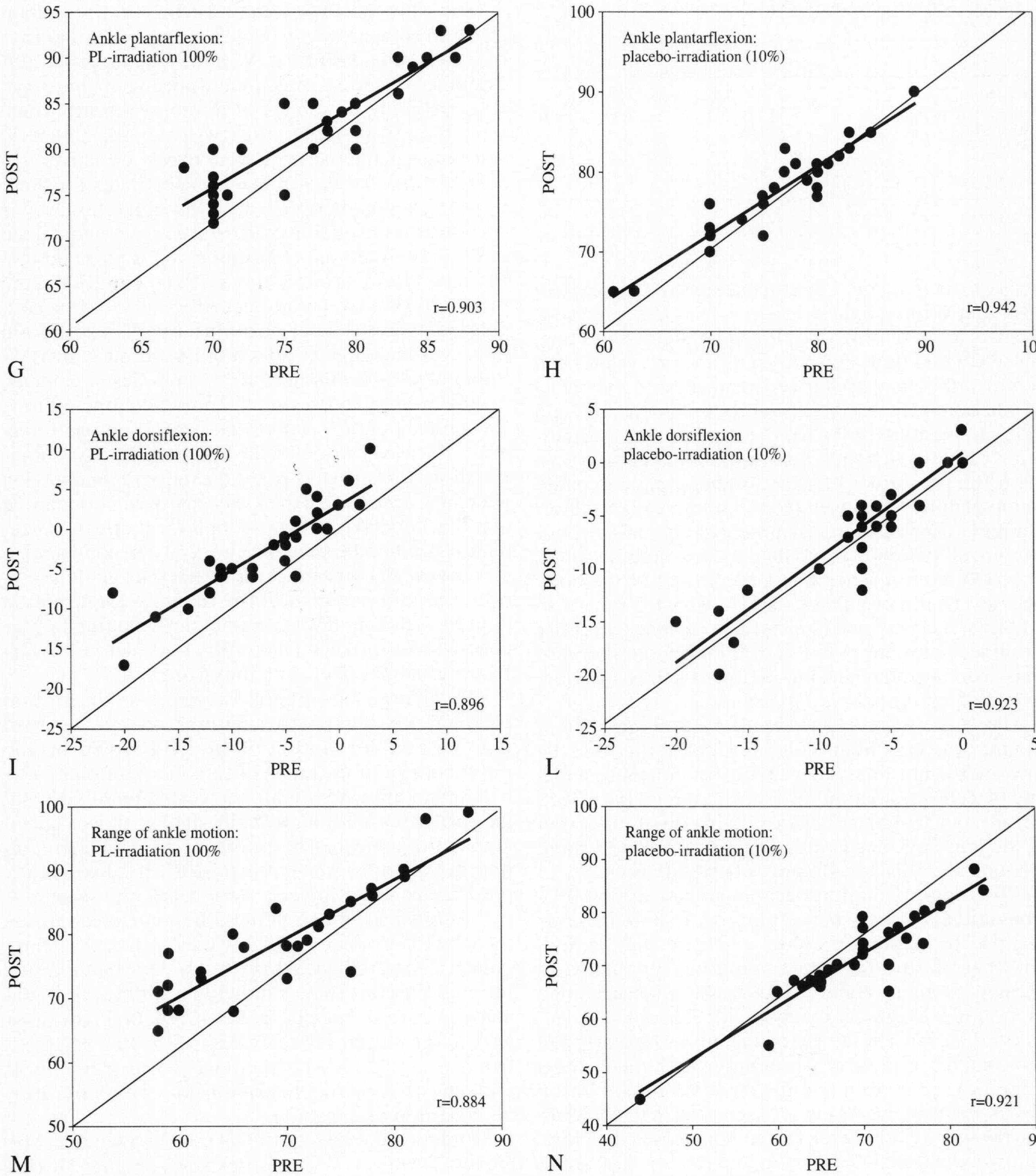

Fig. 3.—G-N) Scatter diagram for the range of ankle motion. x-axis: pre-irradiation, y-axis: postirradiation.

TABLE III.—*PL/placebo-irradiation change rate of each range of motion.*

Range of motion	Mean±SD	t
Shoulder		
—PL	8.7±6.06	6.66*
—Placebo	4.5±2.28	
Ankle		
—PL	13.6±6.39	7.14*
—Placebo	3.1±4.67	

*: $p<0.05$.

essary to increase muscle temperature to be more effective.[3] Performing light exercise such as a jogging contributes to increasing muscle temperature, heart rate, muscle blood flow, and body temperature. It has been reported that linear polarized near-infrared light (PL) irradiation increases muscle and skin blood flow, and skin temperature of the irradiated part.[7, 12] PL-irradiation can give light and heat stimulation to body in a short time because of its great light output compared to the helium neon laser and the semiconductor laser similarly used as a laser treatment in clinical settings. Moreover, it is considered that the heat stimulation of PL-irradiation reaches the deep dormal of the body because of the wavelength of PL (0.6-1.6 ì m).[13] In addition, it is very practical because anyone can easily provide treatment.[14] If PL-irradiation can increase muscle temperature and blood flow, it will be an effective method to improve flexibility.

The trial-to-trial reliability of each range of joint motion was very high. There is a possibility that the measurements of the range of joint motion before PL- and placebo-irradiations produced a stretching effect, because each subject performed maximal extension of the muscle for each measurement. However, there were no significant differences between trials.

All ranges of motion became greater in post-PL-irradiation, similarly in postplacebo. In post-PL-irradiation, the angle of shoulder extension and flexion, and that of ankle plantarflexion and dorsiflexion became greater by about 5° (3.1-8.1%), and each range of motion was greater by about 10° (shoulder: 4.4%, ankle: 13.2%). These improvements were nearly the same degree as those of warming-up by light exercise (jogging) for 10 min and the stretching done in the pre-experiment. Moller *et al.*[15] reported that isometric and passive stretching for 15 c min increased the range of hip abduction, knee flexion, hip flexion, and ankle dorsiflexion with the knee flexed and straight by about 4-17%. Although PL-irradiation in this study was short (10 min) compared with their study, a similar improvement was found. Further, Wiktorsson-Moller *et al.*[16] examined the effect of general warming up, massage, and stretching on ranges of motions, reporting that stretching was most effective, whereas general warming-up and massage were hardly effective. It is possible that the PL-irradiation substitutes for these warming-up methods, because PL-irradiation in this study was more effective than the equivalent obtained in the other methods. Wajima *et al.*[7] suggested that PL-irradiation around the stellate ganglion area increased skin temperature and blood flow. It is considered that the heat stimulus by PL-irradiation improves the range of joint motion, because the flexibility of soft-part tissues, such as muscles or tendons, is improved by increasing the muscle temperature.

Shiraishi *et al.*[13] report that irradiation itself may affect muscle exertion by the influence of psychological factors. Also in this study, the range of joint motion after the placebo-irradiation was improved. It is inferred that this depends on the psychological effect of irradiation itself or the stretching effect by extending muscles maximally when measuring the joint angle. However, the improvement of the range of joint motion after PL-irradiation was greater than that after the placebo-irradiation. It is, therefore, considered that the PL-irradiation effect is an improvement.

The change rate of the range of ankle motion between pre- and postirradiations was greater than that of shoulder motion (Table III). However, the improvement of the range of shoulder motion by PL-irradiation appeared in all subjects (Figure 3A) and the change tendency after PL-irradiation almost agreed among the subjects. On the other hand, ankle motion improved in most subjects in post-PL-irradiation over pre-PL, but some subjects were nearly the same.

Presumably the individual difference of improvement by PL-irradiation for ankle motion is, therefore, greater compared with that for shoulder motion. It is inferred that the greater individual difference in the ankle occurred, because ankle irradiation was done with many muscles besides the tendon (the Achilles' tendon) compared with shoulder joint irradiation. It will now be necessary to examine more effective irradiation parts of the ankle.

Moreover, the effect of PL-irradiation tended to be greater in subjects with low flexibility (Figure 3). This tendency, especially, was remarkable for the ankle joint. Matsuzawa *et al.*[17] also examined the effect of PL-irradiation on the range of ankle motion, reporting that although the range of a motion tended to become greater by 2-3°, there was no significant increase. The disagreement of the result may depend on a difference in the irradiation time, irradiation position, and so on. Furthermore, there is also a possibility that a remarkable effect was not found, because the subjects in their study had superior ankle flexibility compared with those in this study, being greater by about 10° at a mean value. We cannot judge only from the present results that the sensitivity for PL-irradiation or the effect of general warming-up relates to superior or inferior flexibility. However, there is a possibility that subjects with superior flexibility limit the range of motion because of the limitation of the skeletal structure, even if soft-part tissues, such as muscles and tendons, still have room for extension. It is suggested from the present results that PL-irradiation improves the ranges of shoulder and ankle motions, and it is effective as a warming-up method. The PL-irradiation is a complex procedure as compared with simple muscular warming-up. However, the PL-irradiation is considered to be a complementary method to effectively improve the range of joint motion closely related to important motion for competition or exercise.

This study selected the shoulder and ankle joints to examine the effect of PL-irradiation for the range of a motion related to relatively small muscles and tendons, because PL-irradiation is a spot type, stimulating 1 point on the skin. It will, therefore, be necessary to examine the effect of PL-irradiation on relatively large muscles and tendons such as the trunk anteflexion or dorsiflexion. Moreover, further study would need to examine more effective irradiation points, and to compare with general warming-up methods such as stretching, massage, or light exercise.

Conclusions

From the results of this study, the following conclusions are warranted; 1) the ranges of shoulder and ankle motions become greater by PL-irradiation, 2) a larger individual difference is found in the effect of PL-irradiation in the ankle joint compared with the shoulder, 3) the effect of the PL-irradiation for the ranges of shoulder and ankle motions tends to be greater in subjects with a low range of joint motion compared with ones with a high range.

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