CORRELATION OF PSYCHOMOTOR SPEED AND PHYSICAL PERFORMANCE OF SKILLED AND NON SKILLED ATHLETES TRAINING IN DIFFERENT SPORTS

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ชื่อวิทยานิพนธ์ ศึกษาหาความสัมพันธ์ของความเร็วไซโคมอเตอร์กับสมรรถภาพร่างกายในนักกีฬาที่มีความชำนาญ แตกต่างกันในกีฬาแต่ละประเภท

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บทคัดย่อ

ในการวัดความเร็วของไซโคมอเตอร์นั้นแบ่งตามชนิดของเครื่องมือที่ใช้ซึ่งประกอบด้วยความเร็วของปฏิกิริยาการตอบสนอง, ความเร็วของการเคลื่อนที่, ความเร็วของวงจรรีเฟล็ก, ความสามารถในการแยกความถี่ของการกระพริบของแสง, และอัตราการนับเลขในใจและออกเสียง จากผลการทดลองพบว่า

ความเร็วของการตอบสนองเมื่อกระตุ้นด้วยการสัมผัสที่ส้นเท้า นิ้วนางมือขวาและนิ้วนางมือซ้ายของนักยกน้ำหนักทีมชาติเร็วกว่า นักยิมนาสติกทีมชาติ, นักบาสเกตบอลทีมชาติ นักปิงปองทีมชาติและเร็วกว่านักยกน้ำหนักทีมมหาวิทยาลัย แต่เมื่อกระตุ้นด้วยการสัมผัสที่ต้นคอระดับอะโครเมียมพบว่าความเร็วของการตอบสนองในกลุ่มของนักยกน้ำหนักเร็วกว่ากลุ่มของนักยิมนาสติกและกลุ่มควบคุมเท่านั้น

ความเร็วของการตอบสนองเมื่อกระตุ้นด้วยเสียงในกลุ่มของนักยกน้ำหนักทีมชาติ มีความเร็วในการตอบสนองได้ดีกว่ากลุ่มนักยิมนาสติก, นักบาสเกตบอลและนักปิงปองทีมชาติ แต่ไม่เร็วกว่ากลุ่มควบคุม

ความเร็วของการตอบสนองเมื่อกระตุ้นด้วยแสง ในกลุ่มของนักยกน้ำหนักตอบสนองได้เร็วกว่านักยิมนาสติก, นักปิงปองทีมชาติ, นักยกน้ำหนักทีมมหาวิทยาลัยและกลุ่มควบคุม แต่ไม่เร็วกว่านักบาสเกตบอลทีมชาติ ความเร็วของวงจรรีเฟล็กของเท้าซ้ายในนักยกน้ำหนัก, นักยิมนาสติกและนักบาสเกตบอลทีมชาติ

ใช้เวลานานกว่ากลุ่มควบกุม แต่วงจรรีเฟล็กของเข่าขวาในนักปิงปองทีมชาติเท่านั้นที่ใช้เวลานานกว่ากลุ่มควบคุม แต่เมื่อเปรียบเทียบความเร็วของวงจรรีเฟล็กในนักกีฬาแต่ละประเภทแล้วพบว่าไม่มีความแตกต่างกัน

ความเร็วของการเคลื่อนไหวของเท้าในนักยกน้ำหนักทีมชาติพบว่าช้ากว่านักบาสเกตบอลทีมชาติ นักปิงปองทีมชาติ นักยกน้ำหนักทีมมหาวิทยาลัยและกลุ่มควบคุม แต่การเคลื่อนไหวของมือในกลุ่มของนักยกน้ำหนักทีมชาติพบว่าไวกว่ากลุ่มของนักยิมนาสติกและกลุ่มควบคุม

ในนักยกน้ำหนักมีความสามารถในการแยกความถี่ของการกระพริบของแสงด้วยความถี่ที่สูงกว่านักยิมนาสติก, นักบาสเกตบอล, นักปิงปองทีมชาติ แต่ไม่มีความแตกต่างจากกลุ่มควบคุมและในกลุ่มนักยกน้ำหนักทีมมหาวิทยาลัย อัตราการนับเลขในใจและออกเสียงในกลุ่มของนักยกน้ำหนักทีมชาติใช้เวลาน้อยที่สุดเมื่อเปรียบเทียบกับกลุ่มนักยิมนาสติกทีมชาติ, นักบาสเกตบอลทีมชาติ, นักปิงปองทีมชาติและกลุ่มควบคุม

จากข้อมูลของความเร็วไซโคมอเตอร์แสดงให้เห็นว่านักยกน้ำหนักมีความเร็วไซโคมอเตอร์ที่ดีกว่านักกีฬาประเภทอื่น เช่นความเร็วของปฏิกิริยาการตอบสนอง, ความเร็วของการเคลื่อนไหว, ความสามารถในการจำแนกความถี่ของการกระพริบของแสง, อัตราการนับเลขในใจและนับออกเสียง ซึ่งได้อธิบายผลของการศึกษานี้ในเชิงของการเปลี่ยนแปลงทางด้านสรีรวิทยาและระบบประสาทหลังจากการฝึกซ้อม นอกจากนี้ยังพบว่าความเร็วไซโคมอเตอร์ต่างๆ เหล่านี้มีมีความสัมพันธ์ซึ่งกันและกัน เช่นอัตราการนับเลขในใจ มีความสัมพันธ์อย่างสูงกับอัตราการนับเลขออกเสียง, อัตราการนับเลขออกเสียงมีความสัมพันธ์เชิงลบกับความสามารถในการจำแนกความถี่ของการกระพริบของแสง, ความสามารถในการจำแนกความถี่ของการกระพริบของแสงมีความสัมพันธ์เชิงลบกับความเร็วของการเคลื่อนไหวของมือขวา, ความเร็วของวงจรรีเฟล็ก มีความสัมพันธ์เชิงบวกอย่างสูงกับความเร็วของการตอบสนอง เมื่อกระตุ้นด้วยการสัมผัสที่ส้นเท้าและความเร็วของการตอบสนองเมื่อกระตุ้นด้วยแสง, เสียงและการสัมผัสมีความสัมพันธ์ซึ่งกันและกัน จากความสัมพันธ์เหล่านี้แสดงให้เห็นว่าความเร็วของไซโคมอเตอร์ชนิด

ต่างๆนี้เชื่อมโยงซึ่งกันและกันในสมองและระบบประสาท และสามารถถูกทำให้เปลี่ยนแปลงได้โดยการฝึกซ้อมที่แตกต่างกัน

Thesis Title Correlation of Psychomotor Speed and Physical Performance of Skilled and Non Skilled Athletes Training in Different Sports

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ABSTRACT

It was found that the hand grip strength and the leg strength of weightlifter national team (W1) was higher than gynmastic national team (G1), weightlifter university team (W2) and the control group. Meanwhile relative hand grip strength of the weightlifter national team was lowest. The maximal oxygen consumption of gymnastic national team (G1), basketball national team (B1) and table tennis national team (T1) were significantly higher than weightlifter national team (W1) and the control group (C). The balance time of all of athlete groups of national team (W1, G1 and T1) were longer than the control group and significantly longest in G1. The flexibility of G1 was highest and higher than W1, B1, T1, C and G2. Physical fitness tests show that the weightlifter had higher strength but lower maximal oxygen uptake (aerobic power) when compare with other sports. The tactile reaction time when stimulated at heel and 4th finger of weightlifter national team (W1) was significantly shorter than gymnastic national team (G1), basketball national team (B1), table tennis national team (T1) and weightlifter university team (W2). However, the tactile reaction time of W1 was only shorter than G1 and the control group when stimulated at the acromium level of the neck.

The auditory reaction time of weightlifter national team (W1) was shorter than G1, B1, T1 but not significantly shorter than the control group. The visual reaction time of weightlifter national team (W1) was shorter than G1, T1 and the control but not significantly shorter than B1. The patellar reflex time of the left leg of W1, G1, B1 was longer than the control but in the right leg, only T1 was longer than the control. The patellar reflex time of the right and left leg of various sports type was not different. The movement time of the leg of W1 was longer than B1, T1, W2 and the control. When compare between the university team, the movement time of W2 was shorter than T2, G2 and the control. The movement time of the hand of W1 was shorter than G1 and the control. The flicker fusion frequency of W1 was higher than G1, B1 and T1 but not different from the control and W2. The verbal and non verbal counting of W1 was fastest when compare with G1, B1, T1 and C.

The data of psychomotor speed show that the weightlifter are faster in psychomotor speeds such as reaction time, movement time, flicker fusion frequency, verbal and non verbal counting when compare with other type of sports. This indicates that there were many physiological and neurological changes after prolong athletic training. In addition, the psychomotor speed also showed relation with different psychomotor tasks such as the verbal counting shows highly positive relation with non-verbal counting, the verbal counting rate was negatively correlated with the flicker fusion frequency (FFF), FFF was negatively related with movement time (MT) of the right hand, the patellar reflex time was highly positive related with the reaction time RT (tactile at Rt heel). The visual, auditory, tactile RT were related together. The above data indicate that psychomotor speeds can be altered by different programs of athletic training.

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ABBREVIATION

Ach = Acetylchcline

CRT = choice reaction time

CT = contraction time

EMG = Electromyographic

FFF = Flicker Fusion Frequency

FT = Fast Twitch Fiber

HR = heart rate

Hz = Heartz

Kp = kilopound

LAT = Reflex latency

LBT = Left Bigtoe

LI = Left Index

MT = Movement time

PMT = Premotor time

RBT = Right Bigtoe

ResT = Response time

RI = Right Index

RT = Reaction time

SRT = Simple reaction time

ST = slow twitch fiber

TRT = Total patellar reflex time

CHAPTER I

INTRODUCTION

Psychomotor speed is the fastest speed with which an individual can perform a task which involves reacting motorically to an environmental stimulus. Tasks used to assess psychomotor speed are tasks such as simple and choice reaction time,tapping,movement time(Spirduso,1980). In addition, flicker fusion frequency can be an index showing visual sensory integrity. There are some evident that high fitness individuals response very quickly to stimulus and that aerobic training decrease response latency. Both simple and choice reaction times have been found to be significantly faster in young athletes than in young non athletes (Spirduso, 1980). In 1984, Dustman et al provide different groups of subjects from 55 to 70 year of age with four-month training program. Result showed faster simple reaction time in the aerobically trained subjects, who had improvement in maximum oxygen uptake but not in the subjects who given a general fitness program (no significant change in oxygen uptake). These results suggest that aerobic exercise at high intensity may shorten reaction time among the the elderly. However, in 1990 Roberts studied the effect of 6 wks walking program on RT and MT among 52 elders. He found that RT and MT were not shorten with life-long parcipitation in aerobic activity (Robert, 1990). However, Panton et al (1990) found small significant relationships between maximal oxygen consumption and RT and MT. Then Roberts (70) suggested that the measure of aerobic capacity would further clarify the effect of this capacity on RT and MT.

The ability of an individual to react to an external stimulus shows the level of his sensory-motor co-ordination. The reaction time of an individual is varying according to specific physical activity in which he is specializing. Therefore, the reaction time is great importance in sports. Some sports events require relatively faster reaction as compared to others. Bhanot and Sidhn (1979) study the reaction time of Indian Hockey players with reference to three levels of participation, NIS (National Insatitute of Sports) trainees, Combined university and national junior. The results showed visual and auditory reaction times of hand and foot in combined university hocky player and National Junior were faster than NIS trainees. In 1989, Harbin, et al (41) studied about the occulomotor response in relation to sports performance and found that RT between football and basketball player were not significantly different. There was a significant difference between professional and amateur response times. The professional athletes had a response time shorter than amateur athletes. These mean that professionals response was faster. Harbin (41) suggested that response time may be useful in determining athletic potential.

From various reports, it is still not clear whether aerobic training can improve psychomotor speed. However, it shows some difference in the psychomoto speed between skilled and non-skilled athletes. There are several questions about these such as, what is the relationship between psychomotor speed and athletic performance and what effect does training have on response time? If response time is improved with training of sporter, whether or not other psychomotor speed tests for example flicker fusion frequency and reflex time are also improved with it? The last question is that whether or not the different training programs have different effect on psychomotor speed. The following investigations were done to answer these questions.

CHAPTER II

LITERATURE REVIEW

Skill

Skill is an indicator of proficiency, of a person who exhibits competence in carrying out a task.Such a person is called skilled or skillful. Over many performances the skill level may change. In learning a task an individual can go from a poorly skilled to a highly skilled level by regular practice. A skilled performance is characterized as one who can produce an output of high quality with a good deal of consistency. Skilled performance is also characterized by an appearance of ease, a smoothness of movement and anticipation of variations in the stimulus situation before they arrive and an ability to cope with these and other disturbances.

Motor skills task

In general, the tasks can be classified into four categories : tasks for measuring time and speed, tasks for measuring accuracy, tasks for measuring extent of performance and secondary tasks. Two of the most important variables of motor behavior are speed of reaction and speed of movement. Because psychomotor speed is the speed with which an individual can perform a task which involves reacting motorically to an enviromental stimulus. Then, tasks used to assess psychomotor speed are task such as simple and choice reaction time, tapping test, movement time and response time. These task requires fast motor organization, integration, and excertion (Spirduso 1980).

Psychomotor task

I. The reaction time

The reaction time (RT) is the period between the time when the stimulus is given and the point where the subject react (Hascelik et al 1989).

Reaction time component

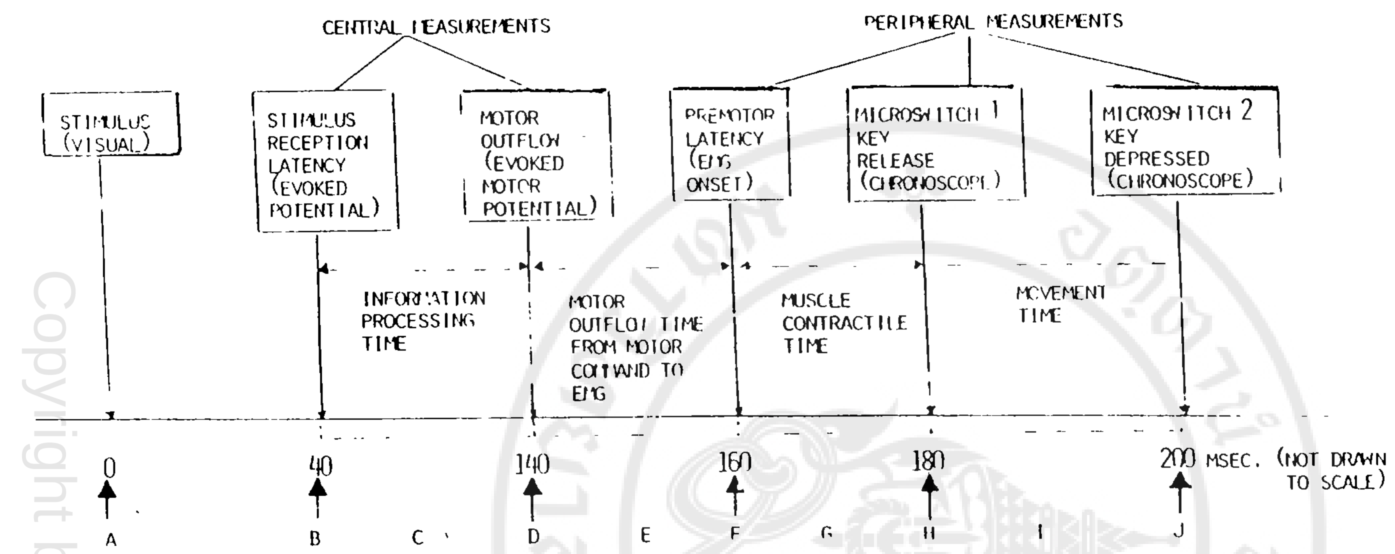
Reaction time can be fractionated by electromyography (EMG) technique into two components.

1. Premotor time (PMT) is the time from stimulus onset to the appearance of an action potential at the involved muscle (Clarkson 1978). Spirduso suggested that it is a central component (Spirduso 1980) (Fig. 1). It can be further divided into two components.

1.1 Reception time : this is the period between the moments where the stimulus is given and perceived (Hascelik, et al 1989).

1.2 Decision peroid : this is the time necessary for the response to perceived stimulus (Hascelik, et al 1989).

2. Motor time is the time from the appearance of the action potential to initiation of limb movement



A = VISUAL STIMULUS INITIATED; CHRONOSCOPES INITIATED
B = EVOKED POTENTIAL IN OCCIPITAL CORTEX
C = D-B; DEPENDANT ON TASK COMPLEXITY
D = EVOKED POTENTIAL IN MOTOR CORTEX
E = F-D; NERVE CONDUCTION TIME, INCLUDING AN UNKNOWN BUT RELATIVELY SMALL NUMBER OF SYNAPTIC TRANSMISSION TIMES SUPRASPINALLY AND AT THE SPINAL MOTOR POOL
F = ONSET OF ELECTROMYOGRAPHICAL INTERFERENCE PATTERN
G = H-F; DEPENDENT ON MECHANICAL AND ELECTRONIC CHARACTERISTICS OF MICROSWITCH CIRCUITRY
H = REACTION TIME; RELEASE OF MICROSWITCH AND TERMINATION OF FIRST CHRONOSCOPE
I = J-H; DEPENDENT ON DISTANCE BETWEEN MICROSWITCHES
J = DEPRESSION OF MICROSWITCH AND TERMINATION OF SECOND CHRONOSCOPE

Fig. 1. Fractionation of a reaction time task into central and peripheral components. This is a conceptual schema of the process; differences in methodology and interpretations of components exist among investigators.

(Clarkson, 1978). This time comes from activity of peripheral component (Fig.1) (Spirduso, 1980).

Classification of reaction time

Reaction time can be classified into two different types:

1. The simple reaction time (SRT) is the time from stimulation (using various forms of stimuli) of an appropriate sense organ to the quickest voluntary response of a given effector organ (Chentanez, et al 1988).

2. The choice reaction (CRT) is the total time required for a response involves making a decision (or choice) to stimuli.

The simple RT is shorter than CRT. A simple stimulus which requires little cerebral processing will result in a faster RT than a complex stimulus which require discrimination.

Another way for classification the reaction time by using warned or unwarned (Chentanez, et al 1988).

1. Warned reaction time is obtained from a subject who was warned a few seconds before an actual stimulation; therefore the subject is mentally more prepared to respond to the actual stimulus (Chentanez, et al 1988).

2. Unwarned reaction time is obtained from a subject who is not warned before an actual stimulation : therefore the subject is mentally less prepared to respond to the given stimulus (Chentanez, et al 1988). The warned

reaction time is therefore shorter than the unwarned reaction time because less time is spent in "decision-making" in the brain during stimulus response events.

The factors effecting RT

Age : the reaction time is longer in childhood and it shortens by aging and reaches the lowest level between the ages of 20-30. Afterwards it slowly increases up to 60 years (Bard, et al 1990, Stelmach, et al 1987, Evarts, et al 1981, Sciarretta and Bawa 1990). Henry showed no significant changes in reaction time and MT from ages 15 to 35. Botwinick (1970) have shown that older people do not use advance information for response planning. In 1986 Stelmach found that the slowing of the reaction time in older is due to the increased time required to specify a dimention of movement.

Sex : Males react faster than females at the same age group (Teichner 1954).

Readiness for the test: Subject who are ready for movement react 7% fasther than ones who aren't ready and with relaxed muscle. Prestimulation which informs the coming stimulus initiates the subject's attention so faster RT could be obtained (Smith 1964). Jones 1988 also showed that anxiety before test can prolong the choice reaction time

Stimulus intensity: Higher stimulus intensity causes shorter reaction times not only in normal subjects but in mentally retarded. This relationship is true to an extent that, thereafter increased intensity of stimulus cann't shorter the reaction time (Baumeister, et al 1965).

Response characteristic: Reaction time increase in the key-release condition and a fraction of Motor time (MT) denoted key-press time decreases in the key-press condition (Bjoklund 1991).

Nutrition : The subjects who don't eat breakfast have longer reaction time than the one who do. Heavy breakfast lengthens the reaction time compared to only drinking coffee (Tuttle 1947) but Jacobson and Edgley (1987) found that caffeine 300 mg can effect on reaction time and movement time. Alcohol, lengthens reaction time as well as smoking, has the same effect on the case of visual stimuli (Oborne and Rogers 1983, Teichner 1954).

Fatigue: physiological fatigue prolongs RT although there is no agreement on the significance of the difference. If the subject can heavily adapt to the stimulus, the influence of sleep disorder is so little that it can be said to be ineffective (Szmodis 1977).

Physical activity: RT is shorter in high level competitors than non-athletes, additionally sprinters have shorter values comparing to long distance runner (Bhanot and Sidhn 1979).

Training and physical fitness: High resistance isometric exercise cause 7% reduction in RT while low resistance exercise have no effect on RT (Baer and Gersten 1955). Some investigators have declared that at the end of nine weeks aerobic training programs elicit physical fitness and RT positively.

Disease: Abraham and Birren's (1973) finding that persons with longer reaction times were predisposed to coronary heart disease.

II. Movement time

Definition

Movement time defined as the elapsed time from initiation of the response until a prescribed action is completed (Bjorklund 1991).

Effecting factors

Sex : Men slightly faster than women.

Age : The slowing of movement speed occurs with advanced age (Stelmach, et al 1987). While no significant change in movement time from age 15 to 35 years.

Training : Increasing motor strength by weight training can decrease movement time is the situation where there is high external resistance to movement. When there is no or minimal resistance to movement, increasing motor strength will have a minimal effect on speed of movement time (Jensen and Fisher 1979).

The relation between MT and RT

There are two models which describe the relation between RT and MT : the RT-MT independence and the RT-MT dependence (Philips & Glencross 1985). The researcher holding the first model argue that RT and MT reflect independent process stages or processing structures

(Sanders 1983) and the researcher representing the other model argue that RT and MT are linked together more strongly and so are less independent (Fowler et al 1987). But from the study of Bjorklund indicated that the relation of RT and MT depends upon methodology (Bjorklund 1991).

The relationship of physical fitness to psychomotor speed

Koroven (1969) reported that the functional capacity of neuromuscular system is higher in trained than in untrained men, while Gutman and Hanzlikova (1972) suggested that training "should" affect the nervous system. They stated that all trained people are physiologically "younger" than untrained ones in terms of the nervous system. The significantly faster neuromuscular responses of highly trained individuals when compared to untrained individuals has suggested a relationship between exercise and psychomotor speed (Spirduso 1980). It is evident that highly fit individuals response very quickly to stimuli and that aerobic training decrease response latency, provides a basis for anticipating that persons who exercise might maintain neuromuscular response speed throughout the aging process.

Psychomotor speed in athletes

Botwinick and Thompson (1968) found that both simple and choice reaction time have been found to be significantly faster in young athletes than in young non-athletes. They proposed that the athletes were in better physical condition than the nonathletes which the

Table 1. Athletes vs Nonathletes.

Fast		Slow		Source	
	SRT		SRT		
Fencers	(.217)	Nonfencers	(.230)	Pierson	(1956)
Racketball	(.207)	Graduate Students	(.235)	Knapp	(1961)
Athletes	(.148)	Nonathletes	(.176)	Botwinick & Thompson	(1968)
Athletes	(.165)	Nonathletes	(.205)	Wyrick	(1972)
Athletes	(.250) (.241)	Nonathletes	(.260) (.264)	Yandell	(1978)
Skilled	(.249)	Unskilled	(.294)	Beise & Peaseley	(1937)
Athletes	(.290)	Nonathletes	(.343)	Olsen	(1956)
Athletes	(.248)	Nonathletes	(.273)	Youngen	(1958)
Athletes	(.140)	Nonathletes	(.156)	Burpee & Stroll	(1936)
Athletes	(.263)	Nonathletes	(.282)	Burley	(1944)

*SRT = simple reaction time, reported in hundredths of a second. More recently SRT has been customarily measured in milliseconds; all but two of these are very old studies.

athletes are more physically fit than nonathletes. At least eleven studies of athlete-nonathletes comparisons in young persons were assembled by Spirduso in 1980 (Table 1). All report showed faster times in athletes group. Moreover, Bhanot (1979) and Harbin (1989) compared the reaction time of superior and inferior athletes performance. They found that the reaction time of professional was shorter than amateur both hand and foot.

Psychomotor speed in exercising elder

Decreased psychomotor performance is generally accepted as a consequence of aging (Salthouse 1985). Studies have shown that an age-related deterioration of the neuromuscular system causes an inevitable lengthening of both total reaction time and speed of movement. In the report of Birren et al (1979) showed that there was a 20% decline in RT between 20 and 60 years of age. Dustman et al (1984) state that the onset of atherosclerosis and a reduction in ability to efficiently transport and utilize oxygen contribute to reduced cerebral oxygenation in old age that may adversely affect brain function. Baylor & Spirduso (1988), Clarkson (1978), Spirduso (1975) have suggested that physical activity may reduce the effect of age on psychomotor performance. Clarkson (1978) found that individuals who were physically active throughout their lives (mean age = 65 yrs) had faster total RTs than sedentary individuals of similar age. Spirduso (1975) showed that physically active older subjects also had a faster speed of movement. The significantly faster neuromuscular responses of highly trained individuals further support a relationship between physical activity and psychomotor speed. A study by Baylor and Spirduso (1988) compared a small sample of aerobically active women with a nonexercise control group, a total of 16 women, mean age = 53 yrs. The results showed faster premotor time, motor time, total reaction time and speed of movement for the aerobic group. Dustman et al (1984) and Spirduso (1980) have proposed that an exercise-induced increase in aerobic efficiency facilitates the transport of oxygen from the environment to consumer cells in the brain which in turn may improve psychomotor aspects of brain function and related to enhanced cerebral metabolic activity such as an increaed turnover of neurotransmitters (Dustman et al 1984).

Decrements of speed of movement due to aging may be due to a general reduction in strength, a decreae in muscle mass and/or a reduction in the number of normally functioning fiber (Barrett 1972). Thus the increase in speed of movement may be due to an increase in strength by training (Panton, et al 1990).

III. Patellar reflex time

Total patellar reflex times in the intact human have been studied since 1885. Total patellar reflex times is the period between the trigger of stimulus at the tendon and the initial movement of leg (Ryushi, et al 1990).

Reflex time components (Hayes 1972)

The total patellar reflex time (TRT) has been fractionated into two components by the electromyographic technique

1. Reflex latency (LAT): represents the sum of neuronal components of the reflex arc, that is,
    1.1 Setting up the impulse in the muscle spindle by stretching the muscle
    1.2 Transmission to the spinal cord by primary muscle spindle sensory fiber (group Ia)
    1.3 Excitation of motoneurons in the grey matter of the ventral horn of the spinal cord
    1.4 Conduction of the impulse along alpha motoneurons
    1.5 Excitation of the end plate.
2. Reflex motor time (MT): is the time taken for excitation to spread in the muscle and develop sufficient tension to move the limb.

Effecting factors of Reflex time

1. Age: Even simple reflex change with age. The monosynaptic reflex and the long latency reflex are both of much longer duration in preschool children than in the teenage subjects (Sciarretta and Bawa 1990). There is no study as yet, available on long latency reflexes and the modulation of reflex magnitude at different ages in adults. Reflex motor time (MT) has been found to be longer as the age increases (Clarkson 1978).

2. Muscular Fatigue: It has been observed that LAT is not much influenced by severe muscular fatigue caused by isometric and/or isotonic exercise, whereas TRT and reflex motor time (MT) are influenced by such kinds of exercise (Vittasalo and Komi 1980).

3. Types of exercise: Weightlifter have significantly shorter LAT than distance runner, although the differences of TRT and MT between weightlifter and distance runner were not statistically significant(Kamen et al 1981).

4. Muscle types: LAT was shorter in the person who has higher percentage of fast twitch fibers (Ryushi, et al 1990).

5. Nerve length: LAT was longer in the higher subject (Ryushi, et al 1990)

IV. Critical flicker frequency (CFF) or flicker fusion frequency (FFF) is the rate at which successively presented stimuli appear to be fused and perceived as steady and continuous. Flicker fusion frequency is a measure of the fatigue state of the visual (retino-cortical) center of the brain. Marata, et al (1991) studied the visual fatigue which induced by work (keypuncher) by using critical flicker fusion frequency as an indicator. He founded that critical flicker fusion frequency was significantly lower in keypunchers than in the control. Then, Marata proposed that CFF appears to be a good parameter for estimations of chronic visual fatigue. In addition, Flicker fusion frequency rate is an indicator of increased perceptual sensitivity (Schwin 1974, Kirkcaldy 1985). Higher CFF has been found to correlate positively with perceptual sharpening (Schwin et al 1974) and greater ability to discriminate visual stimuli (Kirkclady 1985). Difference species of animal show different CFF rate. The dog and the cat rods showed the discrimination of flicker at much higher rate than human rods (Coile et al 1989). Today, there are many study about the CFF and show that CFF can be varied by many factors such as.

1. Sex and hormone

Ali & Amir 1991 and Ginsburg (1982) found that sensitivity to flickering light and visual acuity are greater in men than women. Because the visual system morphological structures of men and women are differ (Phoenix et al1959). These differentiation may be due to the influence of hormone on neural tissue during early differentiation and in adulthood (Goy and McEwen 1980). DeMarchi and Tong (1972) also reported decreased sensitivity to double flashes at times of menstruation.

2. Age

Misiak 1947 showed that age has a significant effect on CFF. CFF rate decrease in the older.

3. Condition during experiment

CFF under monocular was lower than binocular conditions (Ali and Amir 1991, Loop and Frey 1982). The shorter of CFF in monocular condition because the visual constraints imposed by the monocular viewing condition eliminate some visual cues, such as binocular disparity and convergence. Then viewing an object monocularly for a long time may produce eye strain and fatigue. The absence of certain visual cues plus the eye strain and fatigue might contribute to the lower CFF under monocular condition.

Hypoxia

Cipri and Modugno (1990) tested 14 patients with respiratory disorders and PaO_2 level between 36.5 and 67.1 mmHg. All patients in this experiments showed decrease FFF rate.

Temperature

The raising of the body temperature of 0.5 degrees C enhanced the increasing of the critical fusion frequency (Aceornero, et al 1989)

Noise and Stress

From the studies on the effect of noise (70 and 100 dB) on CFF by Bhattacharya, et al (1990) showed the increased in critical flicker frequency.

Deprivation

Food and water deprivation for a sufficient number of hours can reduce critical flicker fusion frequency (Ali and Amir 1989).

Exercise

The exercise and exercise intensity can effect on CFF. Richards (1981) studied the effect of 3 exercise intensity 40%, 70%, 100% of Vo_2max upon critical flicker frequency. He found that exercise stress at the three intensities employed significantly increase critical flicker fusion frequency.

<u>Sensory receptors</u> (Curtis et al. 1972)

Sensory receptors are found throughout the body and are modified according to the functional specilization of the region. They subserve pain, touch temperature, vibration, proprioception, smell, vision, audition and balance.They are capable of transforming different types of energy into nerve impulses which travel through sensory nerve fibers toward the central nervous system. The sensory receptor are as follow.

<u>Free nerve ending</u>: Free nerve ending are formed by sensory fiber which arborized in various tissues including stratified epithelium, muscle, tendon connective tissue, mucous, serous membranes, and joints. They are considered to be pain receptors and touch receptor.

<u>Encapsulated sensory endings</u>: In these endings the nerve is surrounded by a specialized connective tissue capsule of varying thickness. These include meissner corpuscles, Pacinian corpuscles, muscle and tendon spindles, cylindrical end bulb of Krause, and the end bulb of Golgi-Mazzoni.

<u>Meissner corpuscles</u>: Meissner corpuscles are presumed to subserve touch. They are elliptical and may have from one to five myelinated nerve fibers arborizing in their lamellated capsule.

Pacinian corpuscles: These corpuscles are pressure receptors. They are found throughout subcutaneous tissue and are especially numerous in the hand, foot,many glands, clitoris and penis.

End bulb of Krause and end bulb of Golgi-Mazzoni: These ending contain a single extensively ramified axon within their matrix and are found throughout the body. This organ is presumed to subserve heat and cold.

Sensors for Motor Functions: Muscle Spindles and tendon organs (Schmidt 1989)

Morphology Practically every muscle contains stretch receptors (or sensors) called muscle spindles A capsule of connective tissue encloses a member of muscle fiber that are thinner and shorter than the ordinary muscle fibers. The fibers in the capsule are called intrafusal muscle fibers; the ordinary fibers, which make up most of the muscle and are responsible for the work it performs, are the extrafusal muscle fibers. At each end the muscle spindle is attached to the connective-tissue sheath (perimysium) of an extrafusal bundle,by way of tendon like strands of connective tissue 0.5-1 mm long.

Afferent innervation Ia fiber (afferent fiber) wind several times around the center of the intrafusal fibers forming annulospinal endings. Some muscle spindle also have a second sensory innervation. This afferent fibers are thinner than Ia fiber. It called group II fibers.

Efferent: the motor axons of the intrafusal fibers are thinner than normal. It called A-gamma fibers. The motor end plate are usually located toward the end of the muscle fibers.

Structure of the tendon organ

Tendon organs consist of the tendon fascicles of about 10 extrafusal muscle fibers enclosed in a connective-tissue capsule and supplied by one or two thick myelinated nerve fibers (diameter 10-20 um). The afferent nerve fiber are called Ib fibers. After entering the capsule they divide into thinner branches, eventually becoming unmyelinated, and form highly ramified endings among the tendon fascicles.

Distribution of muscle spindles and tendon organs

The number of muscle spindles per muscle on the muscle's size and function. The number of muscle spindles per gram of muscle tissue is particularly high in small muscles that participate in fine movement, such as the small muscles of the hands (upto 130 spindles/g); it is less than 1 spindle/g in the large muscles near the trunk.

Receptor function of the muscle spindles and tendon organs

Both muscle spindles and the tendon organs are stretch receptors. But there are characteristic differences in the discharge pattern. After muscle were stretched, both extra and intrafusal fibers of muscle spindles were activated.

Spinal Motor Reflexes

The reflex arc comprises the afferents, central neurons and motoneurons consecutively activated during the reflex. The times between onset of a stimulus and action of the effector is called the reflex time. In most cases it is determined chiefly by the conduction time in the afferent and efferent pathways and in the central parts of the reflex arc. To this are added the times required for

1. Transformation of a stimulus into a conducted impulse at the receptor
2. Transmission across synapses at central neurons.
3. Transmission from the efferent pathway to the effector (eg. end plate potential)
4. Activation of the effector by excitation of the membrane (eg. excitation contraction coupling)

Stretch reflex (Monosynaptic stretch reflex(Schmidt et al. 1989)

Activation of the primary muscle spindle ending by stretching the muscle must therefore cause excitation of the homonymous motoneurons. This reflex involves only one synapse, between the Ia fibers and the homonymous motoneuron, and therefore is called the monosynaptic stretch reflex of the musculature. The best known example of a monosynaptic stretch reflex is the patellar tendon "knee jerk". Monosynaptic stretch reflex elicited by tapping a tendon are also given the clinical designation T-reflexes. If Ia afferents of a muscle nerve were stimulated by electrical at popiteal nerve and the response were record by using electromyography at surface or intramuscular, this reflex is called H-reflex. The stretching of the muscle causes activation of the muscle spindles, monosynaptic excitation of the motoneuron and contraction a shortening of the muscle that counteracts the stretching. Thus these reflex was required for postural and load carrying muscular functions. Then it play a role during motor acts in sport such as weight lifting, the take off of a swimmer, or balancing and shifting of the center of gravity in gymnastics (Henatsch et al. 1985)

Reciprocal Antagonist Inhibition

The same Ia afferents coming from a particular muscle can exert, via an inhibitory station, a powerful inhibition on the antagonistic motoneurons. This is called reciprocal antagonist inhibition (Henatsch et al 1985). The inhibitory reflex arc includes a central interneuron and hence is disynaptic. Thus there are two central synapses, one (excitatory between the Ia fibers and the interneurons, and a second (inhibitory) between the axons of the interneurons and the motoneurons.

Autogenetic Inhibition from Golgi Tendon Organs

The Ib afferents from Golgi tendon organs inhibit oligosynaptically their own motoneurons but facilitate the antagonistic motoneurons. This appears like a negative counterpart to the stretch reflex and is called autogenetic inhibition. It was believed, particularly in sports medicine, that their main task was to protect the muscles against excessive tension developments and thus to prevent ruptures of muscle and tendon.

Flexor Reflex Afferents (FRA)

This term refers to a rather heterogenous collection of high threshold afferent of group II-IV originating from tactile ergoceptive and nociceptive receptor in the skin, joints and muscles. Their common name reflects the fact that they elicit frequently ipsilateral flexion responses of a limb, usually combined with ipsilateral inhibition of extensors and a crossed extensor reflex on the contralateral side. However, under other condition, the same afferents can conversely lead to facilitation of extensors and inhibition of flexors, or to mixed effects. Apparently the whole FRA group has at it disposal alternative spinal pathways with contrasting either excitatory or inhibitory effects on their alpha motoneurons. The selecting switch may be shifted by higher motor centers and/or by segmental inflows. The tactile and nociceptive information from the FRA does not always induce the rather disturbing defense reactions, but may also be selectively used for the support of movement components.

Presynaptic inhibiton : a self control of Primary Afferents

The primary afferents send collateral to short chains of spinal interneurons, the last one ending with axoaxonic synapses at the afferent terminals. Synaptic action leads to depolarization of the terminals which will reduce their excitatory transmission potency for the target neurons eg. motoneurons. It is important for motor learning in sport eg. to cut off unnecessary surplus innervations for newly acquired skills.

Recurrent Renshaw Inhibition

Recurrent axons callaterals of the alpha-motoneurons contact and excite a special type of inhibitory interneurones in there vicinity, which are called Renshaw cell. They exert a feedback inhibition on the same and neighboring synergistic motoneurons mainly alpha, but to a lesser degree also gamma motoneurons.

Visual Receptors (Sage 1984)

Two types of visual receptors rods and cones were lines on the retina layer. The shape of rods is long and narrow while the cones are slightly shorter and have a bulblike appearance. Photosensitive chemicals peculiar to rods are excited by light. When light energy impinges on these receptors,. depolarization of the receptor cells occurs. The rods and cones are responsible for different kinds of vision. Rods are photoreceptors most sensitive to light and are, therefore, the primary receptors for night vision. Conversly, cones function best at a high intensity of illumination and so are considered the day photoreceptor. In addition cones contain special photochemicals that enable us to have color vision.

Visual pathway (Schmidt, 1989)

Rods and cones make synaptic connection with bipolar cells. They serve mainly to relay stimulus information from the rods and cones to the ganglion cell. The ganlion cells give rise to the nerve fibers forming the optic nerve. The human optic nerve consists of about 1 million myelinated poorly myelinated and unmyelinated axon. The optic nerves of the two eye coalesce at the base of the skull,forming the optic chiasm; here the nerve fibers from the nasal half of each retina cross to the opposite side. The optic tract leads to the first central station of the visual pathway the lateral geniculate nuclei (LGN), the superior colliculi, the nucleus of the optic tract (NOT), nuclei of the accessory optic tract, the pretectal region of the brainstem and the hypothalamus. These connections serve various functions, as folows.

1. The lateral geniculate nuclei (LGN) functions in the recognition of objects, in color and movement vision and in stereoscopic depth perception.

2. Hypothalamus serves to couple the day/night alternation with the endogenous, circadian rhythm or the sleeping/waking rhythm.

3. Pretectal region serve to regulate pupil size.

4. Optic-nerve axons end on nerve cells in the pretectal nuclei of the "accessory optic tract". The latter communicate with the gaze-control centers in the brainstem, mainly to direct the vertical eye movements and the vergence movements.

5. Superior coliculi serves to control reflex eye movements by saccades.

6. Nucleus of the optic tract (NOT) make conncetions with the vestibular nuclei of brain stem. It serves for perception of one's own movement in space during locomotion.

Visual area

The primary visual cortex (area 17 or V_1 of occipital cerebral cortex) lies mainly in the calcarine fissure located bilaterally on the medial aspect of each occipital cortex. Specific points of the retina connect with specific points of the visual cortex, the right halves of the two respective retinae connecting with the right visual cortex and the left halves connecting with the left visual cortex. The macula is represented at the occipital pole of the visual cortex and the peripheral regions of the retina are represented in concentric circles farther and farther forward from the occipital pole. The upper portion of the retina is represented superiorly in the visual cortex and the lower portion inferiorly. The large area of cortex receiving signals from the macula region of the retina. It is in the center of this region that the fovea is represented, which gives the highest degree of visual acuity.

From the primary visual cortex, secondary signals are transmitted into the visual association areas located to the lateral sides of the primary visual cortex. In these areas, the finer meanings of the visual signals are interpreted.

<u>Auditory pathway</u> (Schmidt, 1989)

The auditory or cochlear nerve is the eight of the cranial nerves. It runs from the cochlear of the ear and enters the brain stem at the lower border of the pons. It immediately divides into two portions: one branch running upwards to the ventral cochlear nucleus and the other to the dorsal cochlear nucleus. The ventral cochlear tract runs to the olivary complex of the same and the opposite side. The dorsal cochleartract crosses to the opposite side and there terminates in the nucleus of the lateral lemnicus. The ascending projections of the cells of the olivary complex are both ipsilateral and contralateral and further proceeds through the interior colliculus and the medial geniculate body to the primary auditory cortex, in the transverse temporal gyri in the upper part of the temporal lobes (Heschl's gyrus). This region corresponds to Brodmann's area 41, most of it is concealed in the depths of the sylvian fissure. Adjacent to the primary auditory cortex are other projection fields of the auditory system, called the secondary auditory cortex (Brodmann's area 42).

The motor cortex

The motor cortex has a primary motor area which located at precentral gyrus and at cytoarchitectonic area 4 of Brodmann. The 5th layer contains a large pyramidal cells, Betz. Area 6 is a secondary motor field, consisting of a medial part, the supplementary motor area, and a lateral part, the premotor cortex. Each part of motor cortex control specific muscle group of the body. The hand and the mouth muscles have almost two-thirds of the total representation in the motor cortex area (Fig.2).

The motor cortex receives its main direct input from the somatosensory area of the cortex. Cells of the somatosensory areas extend forward into the motor area and many of the cells of the motor cortex extend back into the somatosensory area. In addition, Subcortical can influence to the motor area. It come from feedback circuits involving the basal ganglia, cerebellum brainstem and even the spinal cord, as well as from peripheral afferent sources through subcortical nuclei. The motor cortex also serves to coordinate the complex innervations on the motor area from other parts of the CNS.

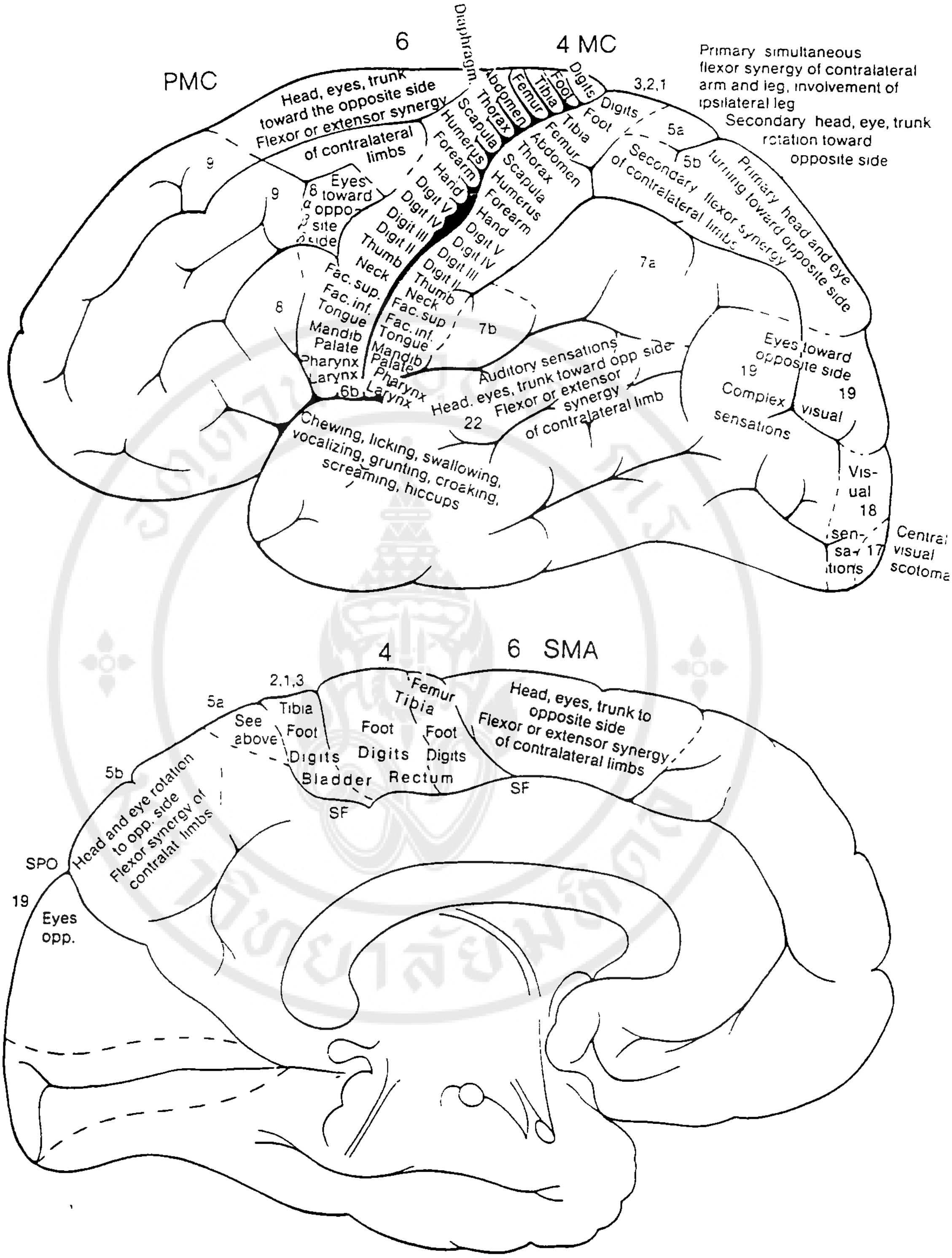


Fig. 2. Map of the human brain, based on motor responses to repetitive electrical stimulation (50 Hz) of the surface of the brain of patients during neurosurgery. The effects of stimulation are entered at the corresponding stimulus sites in the diagram of the brain surface. PMC, premotor cortex or lateral area 6; MC, motor cortex or area 4 (corresponds roughly to the precentral gyrus). SMA, supplementary motor area or medial area 6

Damage or destruction of the motor cortex evokes a loss of the fine voluntary movements, particularly of the finger and feet.

<u>**Motor pathway**</u> (Sage 1984)

There are two motor pathways from the cortex to the spinal cord and the motor nuclei of the cranial nerves are (1) the pyramidal system, also called the corticospinal tract and (2) the extrapyramidal system. These descending cortical and subcortical pathways represent the main instrument by which the brain controls movement.

1. <u>Corticospinal tract (pyramidal tract)</u> (Fig. 3)

These pathway have two types of neurons. One is the huge neurons in the motor cortex called Betz cells which contribute about 3 percent of the total axon of each hemisphere. The second type are small neurons distributed throughout the cortex and having both myelinated and unmyelinated axon. It account for about 95 percent of the total corticospinal tract.

Pyramidal axons leave the cortex, descend in the internal capsule and pass through the pons, giving off collateral axons to the motor nuclei of the cranial nerves for the control of facial, eye and glandular activity. When they reach the medulla, collateral axons innervate cranial motor nuclei for the control of the pharynx, larynx, neck, upper back and tongue muscles. In the medulla, the pyramidal tract axons organize into bundles

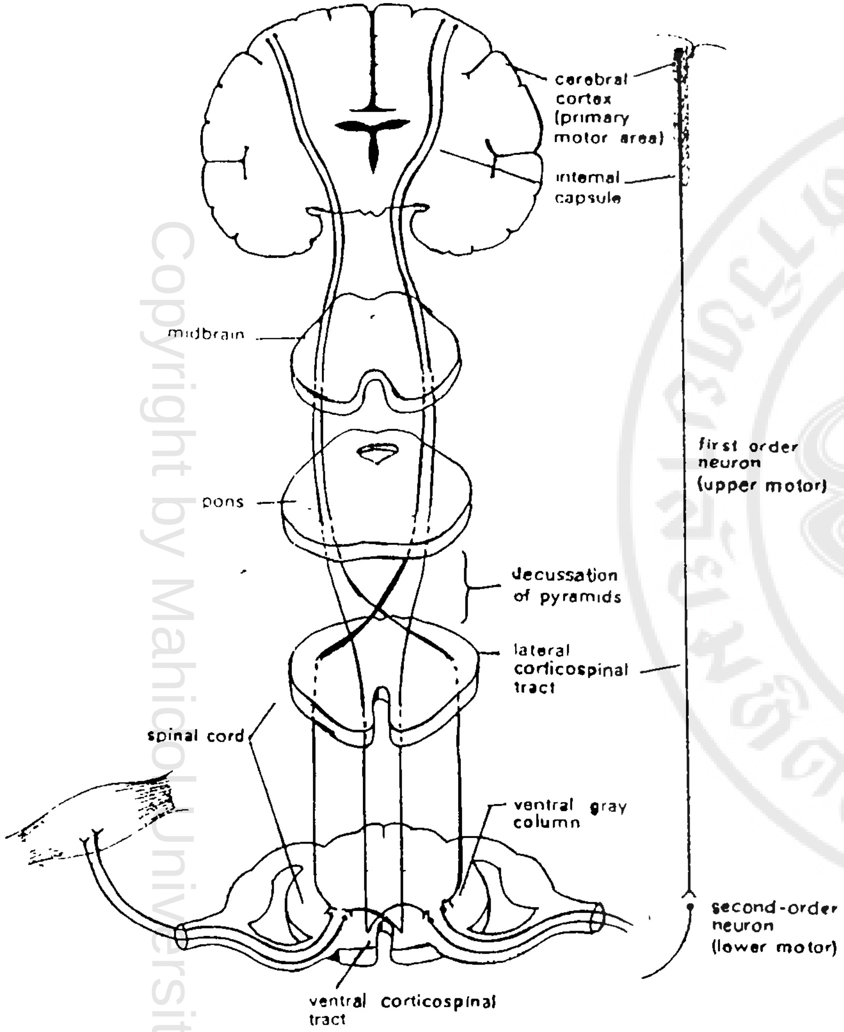


Figure 3 The pyramidal motor pathways

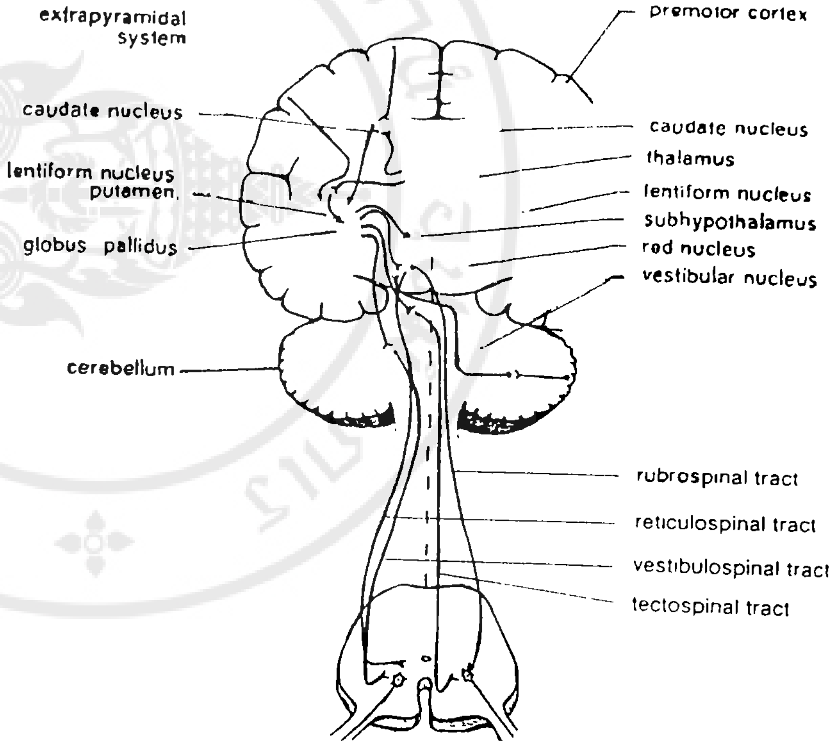


Figure 4 The extrapyramidal motor pathways

of axons on both side of the midline fissure. About 80 percent of the one million axons of each of the bilateral pyramidal tracts cross over the pyramidal decussation and terminate mainly on spinal cord interneurons, which in turn synapses on the motoneurons that control muscle action. About 60 percent end in the cervical region of the spinal cord, while the other half end in lower parts of the cord. Uncrossed pyramidal axons descend in the spinal cord.

The pyramidal system was thought to be responsible for voluntary movements. It specialized in the delicate movements of touching, grasping, and contact-seeking character. In sport performance, it is required for tactile precision movements and finer skills, but not necessarily for gross complex movement.

2. The extrapyramidal system.(Fig. 4) This pathway originates in the motor aea of the cortex as well as in other cortical areas. Axons descend in the internal capsule and many terminate in various subcortical structure, especially the basal ganglia, cerebellum, thalamus and in nuclei of the brain stem. Each of these structures and nuclei in turn has direct or indirect connections with each other.

Extrapyramidal neurons have connections with many subcortical parts of the brain. It is believed that these multiple connections serve to modify some of the operations of the pyramidal system, perhaps helping to refine and smooth out movement. Moreover, extrapyramidal neurons carry a large portion of the impulses for postural adjustment and reflexive movements. Disorders in the extrapyramidal system lead to difficulties in walking, turning and standing up.

The Motor Unit (Astrand 1986)

The motor unit consists of the alpha motoneuron and the muscle fibers which it innervates. When a nerve impulse reaches the motor end plate, Ach is released from presynaptic. The release of Ach affects the muscle membrane, giving rise to an ion flux which reverses the resting membrane potential. The muscle action potential propagates over the membrane and initiates the mechanical chemical mechanisms that cause the myosin and actin in the sarcolemma of the muscle to react. The developed muscle tension will depend on (1) the number of motor units activated and (2) the frequency with which they are stimulated. The skeletal muscle is composed of two main types of muscle fibers with different mechanical properties; type I or slow-twitch fiber and type II or fast-twitch fiber. The time it takes to reach peak isometric tension in human skeletal muscle is reported to be 80 to 100 ms for types I fibers and approximately 40 ms for the type II fibers (Saltin and Gollnick, 1983). The speed of contraction is proportional to the activity of the myofibrillar (myosin)ATPase activity of the fibers. The fast-twitch fibers are innervated by larger motoneurons than the slow fibers. Each motor unit is composed of only one kind of fiber.

Mental Fatigue (Schmidt 1989)

Mental (central) fatigue causes reduced performance because central-nervous control is disturbed. Among the typical symtoms are slower information transmission, deterioration of thought and decision processes, and impaired sensory perception and sensorimotor functions.

Situations eliciting mental fatigue include

1. prolonged work demanding close concentration, extreme mental alertness or dexterity
2. hard physical labor
3. unvaried work under monotonous conditions
4. noise, poor lighting and uncomfortable temperatures
5. conflicts worries or lack of interest
6. illness, pain and malnutrition

Central fatigue can be relieved instantaneously under certain conditions. The sudden disappearance of central fatigue is possible implies that neither the accumulation of "fatigue substances" nor the depletion of energy, reserves is a critical factor. Rather, central fatigue is though to involve the reticular formation, the activity of which is affected not only by intense mental activity but also by monotony.

The occurrence of central fatigue during physical work could be caused by afferent input from the working muscles to the cerebrum, which not only generates the conciousness that the muscles are tiring (or even pain), but also suppresses cortical functions (and hence produce central fatigue).

CHAPTER III

OBJECTIVES

The purpose of this study was to examine:

1. The relationship between different training program in different sports and psychomotor speed.

2. The relationship between psychomotor speed and physical performance parameters eg. $Vo_2 max$, strength etc.

3. The change in RT in various sensory motor neuronal circuits eg. eye, ear, tactile and response at hand and leg in athletes trained in various sports.

4. Psychomotor speed between three level of participation (skill, non skill athletes and control)

5. Correlation among various psychomotor speeds eg. Reflex time VS. Reaction time.

CHAPTER IV

MATERIALS AND METHODS

Equipments

1. Stethoscope and sphygmomanometer (AIL-K_2, Japan)
2. Weight and height balance (Lion Brand, Japan)
3. Lange skinfold calipers (Cambridge Scientific Industries, England)
4. Hand grip dynamometer (Takei co, Ltd, Japan)
5. Back and Leg dynamometer (Takei Kiki Kogyo co, Ltd, Japan)
6. Bodyguard ergometer 990 (Sandness, Norway)
7. Reaction timer apparatus (constructed by Faculty of Science, Mahidol University) consisted of the following companents
    - 7.1 A Stimulus unit compose of 3 types
        - 7.1.1 The red light
        - 7.1.2 The tactile stimulator
        - 7.1.3 The Auditory stimulator (2800 Hz)
    - 7.2 A Stopper microswitch key board with a press button activated by about 5 mm movement of finger or bigtoe
    - 7.3 A Digital watch counting the time between stimulus "on" and response "off" in 1/1000 of a second (Constructed by Mr. Supreecha)

8. A digital watch (construted by Mr. Supreecha; Faculty of Science, Mahidol University) was applied to record the reflex time
9. A stop watch (Hanhart profite J, W. German)
10. Grass stimulator (Grass Instrument, Massasusate USA)

Subject:

The subjects were 69 male volunteers, age between 16-30 years old. All of the subjects were right-hand dominant. They were divided into 4 groups according to the type of sport which they participate as a criteria. In the sporter group, they were further divided into skilled and non-skilled player. Skilled were the national teams. Non-skilled were university team player or junior player. The control group were sedentary who were not engaged in sports of any type of a regular basis. After orientation about protocols, the subjects signed the inform consent form. Medical histories and review of current medication, health status, neuromuscular status were asked to identify current and past medical neurological problem. After the subjects rested, the physical fitness were tested.

I. The physical fitness determination

1. Vital signs recording

Heart rate (HR), systolic and diastolic blood pressure were recorded at the begining for screening the healthy condition of the subjects prior to the physical fitness testing.

2. Antropometric measurement

Weight and height were measured. Skinfold was measured at the middle belly of the right biceps, triceps, right subscapular and right suprailiac region, by using lange skinfold calipers (Cambridge scientific industried, England). The percentage of body fat were determined by Siri's equation:

Body fat (% fat) = ((4.95/body density)-4.5)x100

Body density was calculated from the following equation

Body density = 1.162-0.0630 log x (for subject's age <20 years)

= 1.1611-0.0632 log x (for subject's age >20 years)

where x is the sum of skinfold thickness of every site measured

The lean body mass was calculated from the following equation

Lean body mass (LBM) = body weight (1-(%fat/100))

3. Muscle strength measurement

Muscle strength of hand and leg were tested by using hand grip dynamometer (Takei Co, Ltd, Japan) and Back and leg dynamometer (Takei Kiki Kogyo Co, Ltd, Japan)

The flexibility of the trunk were measured by the ability to flex the trunk (Takei Kiki Kogyo) and to stretch the back (Takei Kiki Kogyo).

4 Maximal O_2 consumption

Each subject sat on the mechanically braked bicycle ergometer which the height of the seat was adjusted appropriately. Cycle ergometer was set at an initial load of 2 kp, then started pedalling at 50rounds per minute (rpm) and started the timer. If the heart rate exceeds about 130 beats per min, the load can be considered adequate and the test can be discontinued after 6 min. If the heart rate is slower than about 130 beats per min after some minutes of exercise, the power should be increased by 0.5 kp. The pulse rate should then be taken every minute and the mean value of the pulse rate at the fifth and sixth minutes is taken as the heart rate response to the exercise demand.

If the difference between these last two pulse rate exceeds 5 beat.min^{-1}, the exercise time should be prolonged one or more minutes until a constant heart rate level is reached. The maximal oxygen uptake was predicted from the steady heart rate and the power setting on the ergometer by using the Astrand monogram (Astrand, 1986).

II. The psychomotor determination

1. The reaction time determination.

After the resting time, each subject was asked to sit comfortably on a chair behind a desk which his forearm was rested on. The red light and auditory stimuli were placed on the desk and in front of subject. The subjects placed the right or the left index finger lightly on the microswitch of the reaction timer which was placed on the desk, and be ready to push the key as fast as possible after sensing the stimulus in order to stop the timer. Before stimuli, subjects were warned by verbal signal "Ra wang" 2-4 sec before each stimulation to produce alert stage (Blocking of the Alpha wave which usually occure at occipital locations). Subject push the key as fast as possible after sensing the stimulus. The right and the left bigtoe were also used as the effector organs. The foreleg were set perpendicular to the floor and the right and the left bigtoe were placed lightly on the microswitch which were transfered to the floor. The right and the left bigtoe push the microswitch as fast as possible after sensing the stimulus.For the tactile reaction time, the tactile stimulus locations were at the right and the left heel, the acromium level of the neck, the right and the left distal 4th finger. The effector organs were the same as the above.

The tactile microswitch was embeded in a tactile stimulator. The timer will be started when the tactile microswitch touches the skin of the above mentioned tactile stimulus location. The effector organs were the same as the above stimulations. The subject was instructed to push the microswitch to stop the timer as fast as possible.

2. The determination of the movement time of hand and foot.

The reaction timer which was constructed by Faculty of Science, Mahidol University were used for recording the movement time, after unwarned reaction time was tested. Each subject was asked to sit confortable on chair and place his hand on the centre of a 31 cm radius circle placed on the desk in front of the subject. The red light was used as a stimulator and the microswitch stopper were placed next to the stimulus. The stimulator and the stopper were placed at the circumference of the circle and transfered to different direction 0°, 90°, 180°, 270°. After sensing the stimulus, subject move his effector organ (the right and the left hand) to push the stopper as fast as possible. Response time was determined three times. The 52.5 radius circle was used for testing the movement time of the right and left leg. Each subject was asked to stand at the centre of the circle. The subject would move his foot to stop the timer at the circumference of the circle as fast as possible after the light is stimulated at 0°, 90°, 180°, and 270° directions. The response time (ResT) of the right and the left leg were tested three times the same way as the response time of the hand. The unwarned reaction time (RT) of each leg and and hand were also determined. Finally, the movement time was calculated from the formular

Movement time (MT) = ResT - RT

3. The reflex time

Each subject was requested to sit on an experimental chair which the lower legs of the subjects hung down freely and vertically with a 90° knee angle during the patellar reflex measurment. The hammer embed with microswitch which was connected with the reaction timer was dropped from an angle of 90° with respect to pattellar tendon. Upon striking the right and the left patellar tendon, a microswitch embed in the hammer head started the timer. A second microswitch located directly in front of the subject's foot,any movement of the subject's lower limb in a forward direction activate the switch to stop the timer. The period of time between the hammer strike and the initial movement of the leg was taken as reflex time. The reflex time was tested with the right and the left leg and determined three times for each leg.

4. The verbal and non-verbal counting determination

Each subject was asked to count the number 1 to 10 in Thai language as fast as possible both verbally and non verbally. The stop watch was started when the subject was signaled to start counting and was stoped when the number 10 was reached. The verbal and non-verbal counting tests were repeated three times.

5. The determination of Flicker fusion frequency (FFF)

The flicker light was from the Grass Stimulator (Grass Instrument, Quincy USA). The stimulator was adjusted to 10 msec of duration time, 10 msec of delay time, and 10 volts. The flicking of the light was adjusted by the subject at the frequency knob unit until the light appear as continuous light. The flicker fusion frequency were then recorded and tested three times.

Data Analysis

All parameters of psychomotor speed and physical performance were averaged and standard error of mean (+SEM) for each group of subjects was calculated.

The parameters were compared by using student's t-test with the control group and with each other at the same and different levels of sport performance.

The parameters of psychomotor speed were correlated with each other and with the different parameters of physical performance.

CHAPTER V

RESULTS

From Table 2 the hand grip strength of weightlifter national team (W1=56.15±5.59 kg) was more than the gymnastic national team (G1=42.79±1.9 kg), the control (C=43.5±2.01 kg) and weightlifter of the university team (W2=42.86±2.92 kg). Whereas the relative grip strength of weightlifter national team (W1=60.6±3.5%) was lowest and lower than gymnastic national team (G1=81.8±3.6%), table tennis national team (T1=75.6±3.2%), weightlifter university team (W2=73.2±3%) and the control (C=75.12±3.4%).

The VO_2 max of the weightlifter national team (W1=49.5±3.03 $l.kg^{-1}.min^{-1}$) was lower than Gymnastic national team (G1=59.3±1.52 $l.kg^{-1}.min^{-1}$), basketball national team (B1=59.3±2.4 $l.kg^{-1}.min^{-1}$) and the table tennis national team (T1=64.75±3.04). The VO_2 max of Gymnastic national team (G1=59.3±1.52 $l.kg^{-1}.min^{-1}$) was significantly more than Gymnastic university team (G2=42.38±1.63 $l.kg^{-1}.min^{-1}$) and the VO_2 max of table tennis national team (T1) was more than the table tennis university team (T2=44.55±2.42 $l.kg^{-1}.min^{-1}$).

The balance time of the weightlifter national team (W1=2.44±0.38 Sec), gymnastic national team (G1=3.59±0.76 Sec), and the table tennis national team (T1=2.79±0.55 Sec) were not significantly different from each other but

Table 2 Shows general physical fitness

Parameter	C	W1	W2	G1	G2	B1	T1	T2
Heigh (cm)	166.40±1.69	171.00±1.56* W1G1** W1B1*** W1W2*	165.50±2.40	161.30±2.85	165.60±0.42	185.70±2.36***	171.0 ±1.97*	169.30± 1.65
Weight (kg)	58.10±1.71	96.10±7.60*** W1G1*** W1W2*** W1B1** W1T1***	58.30±2.50	51.97±2.00	55.72±7.74	76.90±2.14	59.8 ±2.50	56.00± 1.15
Relative grip strength (% BW)	75.11±3.40	60.60±3.50** W1G1*** W1T1** W1W2*	73.20±3.00	81.80±3.60 G1B1**	79.10±2.40	65.80±1.40* B1T1**	75.60±3.20	70.90± 2.90
Hand grip(kg)	43.50±2.01	56.15±5.59* W1G1* W1W2*	42.86±2.92	42.79±1.90	43.95±1.60 G2T2*	50.70±2.23*	46.17±1.77 T1T2**	39.60± 1.47
VO₂ max(l/kg/min)	47.60±7.90	49.50±3.03 W1G1* W1B1* W1T1***	47.87±2.60	59.37±1.52*** G1G2***	48.38±1.63	59.30±2.40***	64.75±3.04*** T1T2***	44.55± 2.42
Balance(sec)	1.40±0.31	2.44±0.38*	1.89±0.39	3.59±0.76**	2.73±0.47* G2T2*	-	2.79±0.55 T1T2*	1.62± 0.16
Flexibility(cm)	11.60±2.00	14.00±1.57 W1G1***	15.57±1.95	24.71±2.50 G1B1*** G1T1*** G1G2*	19.00±1.25** G2T2***	12.00±2.09	9.83±1.83	11.88± 0.12
Leg strength(kg)	134.60±6.94	204.89±4.34*** W1G1*** W1B1*** W1T1*** W1W2**	183.86±5.96*** W2G2*** W2T2**	130.86±4.03 G1T1*** G1B1**	141.8±7.06	154.00±6.90*	109.33±8.44*	129.75±14.68
Relative leg strength(%BW)	232.1±10.0	231.60±13.6 W1B1* W1T1** W1W2***	317.00±10.6***	250.4±9.40 G1B1*** G1T1***	254.80±10	199.90±5.00**	177.80±11.20** T1T2*	230.30±22.7
Relative LBM(%)	85.5±0.5	82.00±2.00*	87.7±1.00*	91.00±0.90*** G1W1*** G1T1*	89.00±0.60***	88.00±0.90*	87.00±2.00 T1W1*	86.00±1.00

* significant at P value <0.05 ; above means were significantly when compared with the control
** significant at P valve <0.01 ; below means were significantly when compared with different sporter.
*** significant at P Valve <0.005
C = control ; G2 = gymnastic university team
W1 = weightlifter national team ; B1 = basketball national team
W2 = weightlifter university team ; T1 = table tennis national team
G1 = gymnastic national team ; T2 = table tennis university team

significantly longer than the control group (C=1.40±0.31 Sec).

The flexibility of G1(24.71±2.5 cm) was significantly more than W1 (14±1.57 cm), B1 (12±2.09 cm), T1 (9.83±1.83 cm), the control (11.6±2 cm) and more than Gymnastic university team (G2=19±1.25 cm).

The leg strength of W1 (204.89±4.34 kg) was significantly more than G1 (130.86±4.03 kg), B1 (154±6.9 kg), T1 (109.33±8.44 kg) the control (C=134.6±6.94 kg) and weightlifter university team (w2=183.86±5.96 kg).Relative leg strength of weightlifter national team (W1 = 231.6±13.6%) and gymnastic national team (G1 = 250.4±9.4%) were also higher than basketball national team (B1 = 199.9±5%), table tennis national team (T1 = 177.8±11.2%).

Table 3.1 shows the tactile reaction time when stimulated at the left heel. In the right index (RI) response, the tactile reaction time of weightlifter national team(W1=176.08±5.1 msec)was significantly shorter than Gymnastic national team (G1=203.16±5.7 msec) but not significantly different from those of basketball national team (B1=186.5±6.87 msec), table tennis national team (T1=187.3±7.22) and the control (C=188.4±5.92). In the left index (LI) response, the tactile reaction time of W1 (176.61±5.8 msec) was significantly shorter than G1 (201.59±7.7 msec), B1 (193.07±7.27 msec), T1 (191.8±5.8 msec) but not significantly different from that of the control group (C=188.63±5.98 msec). In the right bigtoe (RBT) response, the tactile reaction time of W1 was

Tabke 3 Shows mean of different psychomotor speed task

Parameter	C	W1	W2	G1	G2	B1	T1	T2
3.1 Tactile reaction time								
Tactile Lt heel(RI)	188.40± 5.92	176.08±5.10 W1G1**	195.70±15.41	203.16± 5.7	210.36±18.71	186.50±6.87	187.3± 7.22	195.25± 8.98
Tactile Lt heel (LI)	188.63± 5.98	176.61±5.80 W1G1** W1B1* W1T1*	190.84±12.28	201.59± 7.7	205.56±15.85	193.07±7.27	191.8± 5.80	195.26± 7.63
Tactile Lt heel (RBT)	214.10± 9.08	201.74±5.80 W1G1** W1T1**	212.07±11.31	236.33± 9.8 G1B1*	215.58±16.13	212.43±5.63	229.9± 8.90	222.66± 9.75
Tactile Lt heel (LBT)	220.18±10.32	204.27±5.10 W1G1*** W1B1*** W1T1*	225.63±16.07	258.80±11.7 G1G2*	208.95±16.37	235.60±5.97	245.4±15.30	234.59±10.67
3.2 Tactile reaction time	C	W1	W2	G1	G2	B1	T1	T2
Tactile Rt heel (RI)	187.00± 5.35	178.34±4.4 W1G1*** W1B1* W1W2*	* 221.57±20.89	* 207.63± 7.3	201.19±13.94	193.14± 6.37	190.7± 8.0	194.21±6.996
Tactile Rt heel (LI)	187.86± 6.74	182.81±4.8 W1G1* W1B1* W1W2*	212.49±17.11	* 210.20±11.4	206.23±15.89	199.92± 8.53	190.3± 7.9	195.25±6.996
Tactile Rt heel (RBT)	209.47± 7.88	200.12±6.3 W1G1*** W1T1**	215.99±13.34	*** 256.34± 8.3 G1B1** G1G2*	214.55±14.74	218.52±10.33	241.2±16.0	213.81±9.93
Tactile Rt heel (LBT)	219.17±11.01	209.72±8.1 W1G1* W1B1*	221.31±12.99	240.44± 8.2 G1T1*	213.52±15.36	231.27± 7.37	247.0±13.4	225.05±9.86

significantly shorter than G1 (236.33±9.8 msec), T1 (229.9±8.9 msec) but not significantly different from that of B1 (212.43±5.63 msec). In the left bigtoe (LBT), the tactile reaction time of weightlifter national team (W1=204.27±5.1 msec) was significantly shorter than G1 (258.8±11.7 msec), B1 (235.6±5.97 msec, T1 (245.4±15.32 msec) but not significantly different from the control (220.18±10.32 msec).

Table 3.2 shows the tactile reaction time of hand and foot when stimulated at the right heel. The right index response shows significantly shorter reaction time in the weightlifter national team (W1=178.34±4.4 msec) than that of the Gymnastic national team (G1=207.63±7.3 msec), basketball national team (B1=193.14±6.37 msec) but not significantly different from the table tennis national team (T1=190.7±8 msec). The left index response shows significantly shorter reaction time in W1 (182.81±4.8 msec) than G1 (210.2±11.4 msec), B1 (199.92±8.53 msec) and shows no significant difference between G1, B1, and T1(190.3±7.9 msec). In the right bigtoe (RBT) response shows significantly shorter reaction time in W1 (200.12±6.3 msec) than G1 (256.34±8.3 msec) and T1 (241.2±16 msec) and G1 had the longest reaction time. In the left bigtoe (LBT) response shows significantly shorter reaction time in W1 (209.72±8.1 msec) than G1 (240.44±8.2 msec), B1 (231.27±15.35 msec) and no significant difference from the T1 (247±13.4 msec). It shows no significant difference between national team and university team except the reaction time of RI and LI in weightlifter national team was shorter than university team. (RI; W1 = 178.34±4.4 msec, W2=221.57±20.89 msec, LI; W1=182.81±4.8 msec, W2 =212.49±17.11 msec) but the reaction time of RBT in Gymnastic national team (256.34±8.3 msec) was longer than university team (G2 = 214.55±14.74 msec). When compared the reaction time in different sporter with control, it showed longer reaction time in Gymnastic national team than the control group in all effector organ except LBT.

Table 3.3 shows the tactile reaction time when stimulated at Lt 4th finger. The weightlifter national team (W1) had the reaction time significantly shorter than Gymnastic national team (G1) in all effector organ (RI; W1=158.06±4.7 msec G1=179.67±6.6 msec, LI; W1=157.98±5.3 msec, G1=176.49±7.6 msec, RBT; W1=190.73±8 msec G1=227.64±6 msec, LBT; W1=184.49±9.4 msec, G1=235.54±12.98 msec). In addition, the reaction time of RI in W1 (151.06±4.7 msec) is shorter than basketball national team (B1=177.4±7.83 msec) but in university team, the weightlifter (W2) had longer reaction time of RBT (223.13±15.76 msec) than Gymnastic (G2=182.81±5.42 msec) and the reaction time of LBT in the weightlifter(W2=232.4± 8.67 msec) was longer than Gymnastic (G2=180.39±5.52 msec). When compare the reaction time between national team and university team; it shows significantly shorter reaction time in weightlifter national team than university team in all effector organ except LI (RI;

3.3 Tactile reaction time

	C	W1	W2	G1	G2	B 1	T1	T2
Tactile Lt 4th finger(RI)	174.41±7.18	158.06± 4.7 * W1G1** W1B1* W1W2*	194.59±18.68	179.67± 6.60	193.42±14.49	177.40±7.83	169.30± 5.40	182.78± 5.69
Tactile Lt 4th finger(LI)	175.29±8.07	157.98± 5.30 * W1G1* W1W2**	210.56±21.23 *	176.49± 7.60	188.75±13.70	169.78±7.77	166.00± 4.60	177.15± 7.53
Tactile Lt 4th Finger(RBT)	199.51±6.65	190.73± 8.00 W1G1** W1W2*	223.13±15.76 W2G2***	227.64± 6.00 ** G1G2***	182.81± 5.42 *	197.40±7.60	209.30±10.98	196.84±10.94
Tactile Lt 4th finger(LBT)	199.42±9.02	184.49± 9.40 W1G1** W1W2***	232.40± 8.67 * W2G2** W2T2**	235.54±12.98 * G1G2***	180.39± 5.52 * G2T2*	202.03±7.83	208.40±10.50	199.13± 7.41

3.4 Tactile reaction time

	C	W1	W2	G1	G2	B1	T1	T2
Tactile Rt 4th finger(RI)	172.12±5.57	159.83±7.4 W1W2*	193.49±16.41	175.50± 8.1	179.08±15.79	165.50±5.13	170.0± 4.8	177.56±8.41
Tactile Rt 4th finger(LI)	179.59±5.19	158.86±5.7 ** W1G1* W1W2*	196.83±19.77	176.81± 8.3	183.46±15.96	160.48±5.07 **	169.7± 4.98	181.21±8.30
Tactile Rt 4th finger(RBT)	202.89±9.19	180.63±8.0 * W1G1** W1T1* W1W2***	228.00±10.67 *	223.83±10.5 G1B1** G1G2***	182.25± 4.55 *	185.38±5.23 B1T1*	207.4±10.1	199.40±6.396
Tactile Rt 4th finger(LBT)	203.56±8.26	185.55±8.8 W1G1*** W1W2**	235.33±17.56 * W2G2*** W2T2*	231.10± 8.4 * G1G2***	182.65± 6.06 * G2T2*	198.21±9.13	206.2±10.4	199.19±6.22

W1=158.06±4.7 msec, W2=194.59±18.68 msec, LI; W1=157.98±5.8 msec, W2=210.56±21.23 msec, RBT; W1=190.73±8 msec, W2=223.13±15.76 msec, LBT; W1=184.49±9.4 msec, W2=232.4±8.67 msec). The reaction time of the Gymnastic national team (G1) was longer than Gymnastic university team (G2) when the effector organ was RBT (G1=227.54±6 msec, G2=182.81±5.42 msec) and LBT (G1=235.54±12.98 msec, G2=180.39±5.52 msec)

Table 3.4 shows the tactile reaction time when stimulated at the right 4th finger. The right index (RI) response shows no significant different in all groups of sporter at the same level. However, when compare between national team (1) and university team (2), the reaction time of the weightlifter national team (W1)=159.83±7.4 msec was shorter than university team (W2)=193.49±16.41 msec. In the left index (LI), weightlifter national team (W1) and Basketball national team (B1) had shorter reaction time than control group (c) (C=179.59±5.19 msec, W1=158.86±5.7 msec, B1=160.48±5.07 msec). When compare with in national team, weightlifter (W1) had the reaction time shorter than Gynmastic (G1) (W1=158.86±5.7 msec, G1=176.81±8.3 msec). The same as RI response, the weightlifter national team (W1) had the reaction time shorter than university team (W2) (W1=158.86±5.7 msec, W2=196.83±19.77 msec). In the right bigtoe (RBT) response shows the reaction time of the weightlifter national team W1 (180.63±8 msec) was significantly shorter than Gymnastic national team (G1=223.83±10.5 msec) and table tennis national team (T1=207.4±10.1 msec) which both G1 and T1 had the reaction time significantly shorter than Basketball national team (B1=185.38±5.23 msec). The reaction time of W1 was significantly shorter than the control group (c=202.89±9.10 msec). Weightlifter national team (W1=180.63±8 msec) was significantly shorter than university team (W2=228±10.67 msec) but the reaction time of Gymnastic national team (G1=223.83±10.5 msec) was significantly longer than university team (G2=182.25±4.55 msec) and in the table tennis shows no significant difference.

The left bigtoe (LBT) shows the reaction time of W1 (185.55±8.8 msec) significantly shorter than G1 (232.1±8.4 msec) but W2 (235.33±17.56 msec) was longer than G2 (182.65±6.06 msec) and T2 (206.2±10.4 msec). When compare with control group, the reaction time of G1 (231.1±8.4 msec) was longer than control (C=203.56±8.26 msec). Other result are the same as that of RBT when compare between national team and university team (W1=185.55±8.8 msec, W2=235.33±17.56 msec, G1=231.1±8.4 msec, G2=182.65±6.06 msec)

Table 3.5 shows the tactile reaction time when stimulated at acromium level of the neck. The reaction time of RI response in the weightlifter national team (W1=149.37±4.5 msec was significantly shorter than Gymnastic national team (G1=172.79±8.8 msec), table tennis national team (T1=163.2±6.5 msec) and the control group (C=164.35±5.95 msec). The reaction time of LI in W1

3.5 Tactile RT when tactile stimulation was at acromium level of the neck

	C	W1	W2	G1	G2	B1	T1	T2
Tactile neck(RT),(RI)	164.35±5.95	149.37±4.50* W1G1* W1T1*	160.41± 8.75	172.79± 8.80	161.23±10.50	161.62± 7.50	163.2± 6.50	174.36± 7.03
Tactile neck (RT),(LI)	169.97±6.55	148.40±4.50** W1G1* W1W2**	177.23±11.08	173.66±11.10	162.84± 7.73	157.66± 4.90	165.3± 4.99	167.56± 6.61
Tactile neck (RT)(RBT)	199.42±8.92	176.89±8.80* W1G1**	192.34±12.66	218.64±11.70 G1B1** G1G2**	174.58± 7.35*	177.34± 4.57*	191.2± 8.60	183.98± 7.70
Tactile neck (RT)(LBT)	200.17±7.66	177.61±7.00* W1G1***	181.74±15.45	224.46±11.70 G1B1*** G1T1* G1G2***	173.62± 6.92**	178.92± 5.90*	194.1± 7.70	182.93± 7.28

3.6 Auditory reaction time

	C	W1	W2	G1	G2	B1	T1	T2
Auditory RT (RI)	234.00±8.73	227.52±7.60 W1G1* W1B1*	243.10±13.74	255.50± 9.96	221.82±16.70	254.57± 9.17	250.8±14.60	231.35±12.71
Auditory RT(LI)	236.94±8.48	228.77±8.30 W1B1*	244.90±14.47	243.07±10.90	225.17±18.35	249.38± 7.87	250.7±14.00	230.65±14.38
Auditory RT (RLB)	263.40±9.24	244.48±7.20 W1G1** W1B1* W1T1*	263.99±15.46	286.84±13.40 G1G2**	228.29±15.88*	275.19±10.87	263.2± 7.80	255.84± 7.31
Auditory RT (LBT)	263.41±9.91	247.39±9.87 W1G1** W1T1*	251.11±18.33	293.17±12.50* G1G2*	239.48±15.67	267.56±12.9	271.4± 8.80	256.16± 8.198

(148.4±4.5 msec) was significantly shorter than G1 (173.66±11.1 msec), the control (C=169.97±6.55 msec) and weightlifter university team (W2=177.23±11.08 msec). In the right bigtoe (RBT), the reaction time of W1 (176.89±8.8 msec), and B1 (177.34±4.57 msec) was significantly shorter than the control group (199.42±8.92 msec). The reaction time of G1 (218.64±11.7 msec) was significantly longer than W1 (176.89±8.8 msec) B1 (177.34±4.57 msec), and G2 (174.58±7.35 msec). In the left bigtoe (LBT), the reaction time of W1 (177.61±7 msec), B1 (178.92±5.9 msec) were shorter than the control (200.17±7.66 msec). The reaction time of G1 (224.46±11.7 msec) was longer than B1 (178.92±5.9 msec), T1 (194.1±7.7 msec), W1 (177.61±7 msec), control (200.17±7.66 msec) and Gymnastic university team (G2=173.62±6.92 msec).

Table 3.6 shows auditory reaction time of RI in weightlifter national team W1 (227.52±7.6 msec) was significantly shorter than Gymnastic national team G1 (255.5±9.92 msec),basketball national team (B1=254.57±9.17 msec) and no significant shorter than table tennis national team (T1=250.49±14 msec). The auditory reaction time of the left index (LI) in W1 (228.77±8.3 msec) was significantly shorter than basketball national team B1 (249.38±7.87 msec) but not significantly shorter than G1 (243.07±10.9 msec), and table tennis national team T1 (250.7±14 msec). In right bigtoe (RBT), the auditory reaction time of W1 (244.48±7.2 msec) was significantly shorter than G1 (286.84±13.4 msec), B1 (275.19±10.87

msec), T1 (263.2±7.8 msec). When compare between national team and university team, the auditory reaction time of Gymnastic national team G1 (286.84±13.4 msec) was significantly longer than Gymnastic university team G2 (228.29±15.88 msec).

In the left bigtoe (LBT), the auditory reaction time of W1 weightlifter national team (247.39±9.87 msec) was shorter than Gymnastic national team G1 (293.17±12.5 msec) and table tennis national team T1 (271.4±8.8 msec) and not significantly different from the basketball national team B1 (267.56±12.9 msec).

Table 3.7 shows visual reaction time of hand and foot in different sporter. The reaction time of both the right and the left index of the weightlifter (W1) were shorter than other sporter (G1) Gymnastic, (B1) Basketball, (T1) Table tennis but not significant except in RI the visual reaction time of W1 (224.59±10.65 msec) was significantly shorter than T1 (254.4±6.9 msec) and the control (C=249.9±8.07 msec), and significantly shorter than the weightlifter university team (W2 = 262.2±11.23 msec). The right bigtoe (RBT), the visual reaction time of W1 (249.96±9.7 msec) was significantly shorter than G1 (277.31±9.4 msec), T1 (284.4±7.7 msec), the control (279.44±10.66 msec) and the visual reaction time of T1 (284.4±7.7 msec) was significantly longer than B1 (262.14±4.53 msec). The left bigtoe, had the same result as the RBT. The visual reaction time of W1 (247.98±8.98 msec) was significantly shorter than G1 (286.06±10.8

3.7 Visual reaction time	C	W1	W2	G1	G2	B1	T1	T2
Visual RT of RI	249.90± 8.07	224.59±10.65* W1T1* W1W2*	262.20±11.23	247.20± 8.8	248.27±18.04	230.08±9.60	254.4±6.9	238.89± 9.43
Visual RT of LI	255.30± 9.15	232.52±10.30 W1W2*	271.17±15.98	251.54±10.6	247.59±19.14	236.52±8.10	255.3±7.5	242.28±11.27
Visual RT of RBT	279.44±10.66	249.96± 9.70* W1G1* W1T1** W1W2*	288.66±14.39	277.31± 9.4	258.77±20.26	262.14±4.53 B1T1*	284.4±7.7	267.03± 7.31
Visual RT of LBT	271.76± 9.15	247.98± 8.98* W1G1** W1T1** W1W2*	279.24±11.63	286.06±10.8	262.99±21.80	263.52±7.20	285.7±7.5	270.74± 7.31
3.8 Patellar Reflex time	C	W1	W2	G1	G2	B1 **	T1	T2
Patellar Reflex time (Rt leg)	130.16±8.83	151.30± 9.5 W1W2***	119.40±2.92 W2T2**	154.28±13.7	132.88±12.42	164.96± 9.63	142.20+21.3	156.57±13.50
Patellar Reflex time (Lt leg)	122.66±3.64	168.67±30.9**	133.73±3.85* W2T2*	168.50±20.1**	143.41±11.31*	164.48±13.9**	144.96±16.2	178.73±20.12**
3.9 Flicker Fusion Freqency	35.33±0.85	36.93±1.24 W1G1*** W1B1* W1T1*	36.49± 1.45	28.91±1.6*** G1B1* G1T1*	36.94±0.58	33.19±0.99	33.25±1.3	35.31±1.66
3.10 Verbal counting	121.34±4.72	112.34±5.86 W1G1* W1T1**	132.06±10.82	127.34±5.1	135.24±5.14*	123.73±3.35	140.05±8.11*	127.80±7.24
3.11 non verbal counting	118.68±4.74	113.29±4.82 W1G1** W1B1* W1T1**	129.29±11.20	139.67±8*	130.87±5.86	127.83±2.73	133.83±6.38* T1T2**	104.06±7.24*

msec), T1 (285.7±7.5 msec) and the control (271.76±9.15 msec). When compare between national and university team, showed that the visual reaction time of weightlifter national team were significantly shorter than weightlifter university team (W2) in all effector organ. (RI; W1=224.59±10.65 msec, W2 = 262.2±11.23 msec, LI; W1 = 232.52±10.3 msec, W2 = 271.17±15.98 msec, RBT; W1 =249.96±9.7 msec, W2=288.66±14.39 msec, LBT; W1 =247.98±8.98 msec, W2=279.24±11.63 msec) but the visual reaction time of Gymnastic, and table tennis national team were not significantly different from the university team in all effector organ.

Table 3.8 shows the reflex time of the right and left leg. All national sporter had the right reflex time longer than the control but not significant except basketball (B1) (C=130.6±8.83 msec, W1=151.3±9.5 msec, G1=154.28±13.7 msec, B1=164.96±9.63 msec, T1=142.2±21.3 msec). The reflex time of the left leg in all national team sporter were significantly longer than the control except table tennis (T1) which was not significant (C=122.66±3.64 msec, W1=168.67±30.9 msec, G1=168.5±20.1 msec, B1=164.48±13.9 msec, T1=144.96±16.2 msec). The reflex time of both left and right leg of the university team were not significantly different from the control group. When compare the reflex time of both right and left leg between the national and university team, the national team shows no significant difference from the university team.

Table 3.9 shows the mean of flicker fusion frequency (FFF) of weightlifter national team (W1=36.93±1.24 Hz) which was significantly higher than the gymnastic national team (G1=28.91±1.6 Hz), basketball national team (B1=33.19±0.99 Hz) and table tennis national team (T1=33.25±1.3 Hz). The flicker fusion frequency of gymnastic national team was significantly lower than the control (C=35.33±0.85 Hz).

Table 3.10 shows the verbal counting in different sporter. The verbal counting of weightlifter national team (W1 1.12±.05 sec) was significantly shorter than gymnastic national team (G1=1.27±.05 sec), table tennis national team (T1=1.40±.08 sec) and no significant shorter than basketball national team (B1=1.23±.03 sec, and the control group (C=1.21±.05 sec). The verbal counting of the university team was not significantly longer than the control group (1.21±.05 sec) except gymnastic university team (G2=1.35±.05 sec) was significantly different.

Table 3.11 shows nonverbal counting in different sporter. The nonverbal counting of weightlifter national team (W1=1.13±.05 sec) was significantly shorter than gymnastic national team (G1 = 1.39±0.08 sec), basketball national team (B1 = 1.27±.02 sec), table tennis national team (T1=1.33±.06 sec). When compared with the control group (C1=1.18±.04 sec), the nonverbal counting of G1 and T1 were significantly longer than the control.

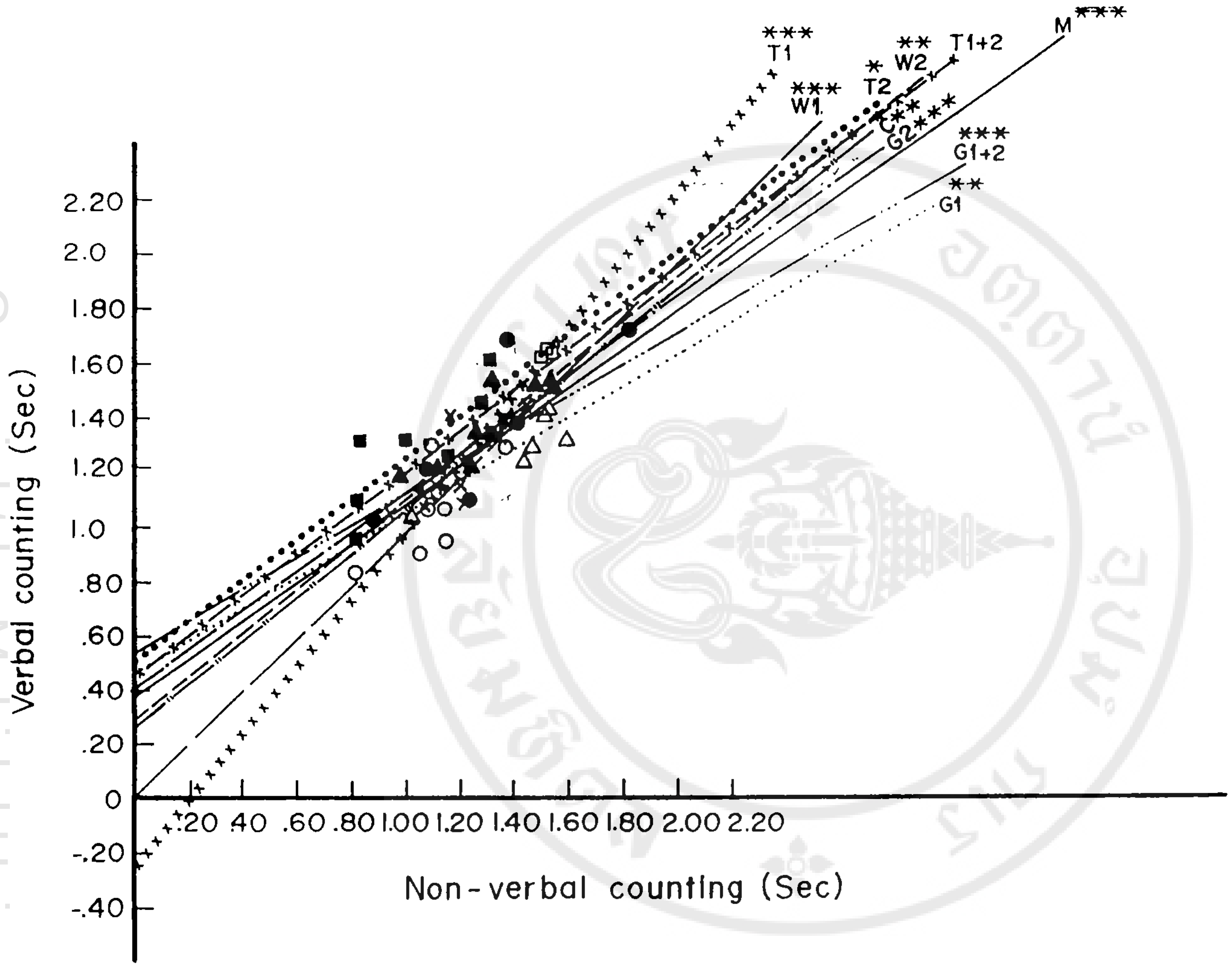


Figure 5. Correlation between non-verbal and verbal counting of different sporter when W=weightlifter, G=Gymnastic, T=Table tennis, C=control, M=Mixture. The number 1,2 mean national and university team respectively.

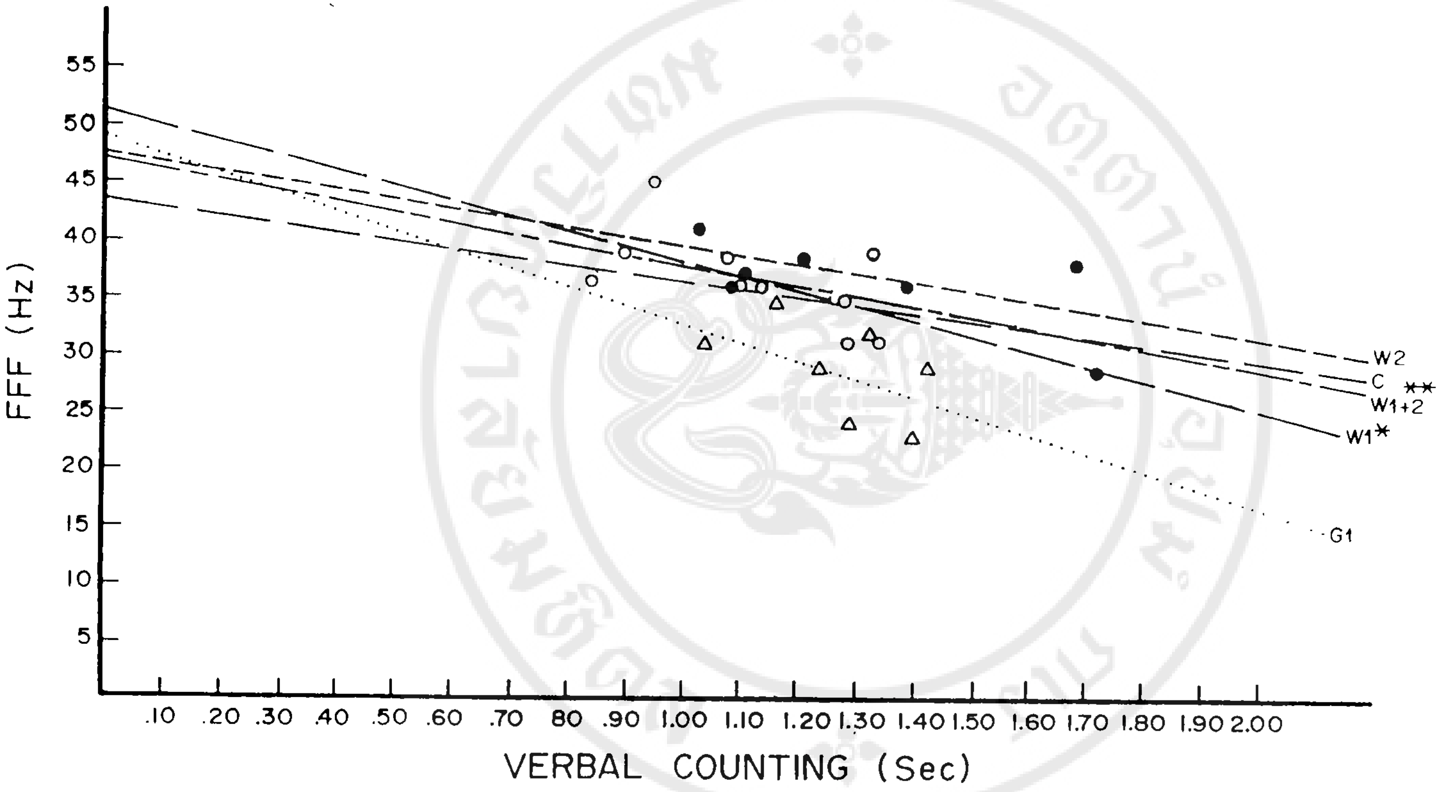


Figure 6. Correlation between verbal counting and flicker fusion frequency of different sporter when W=weightlifter, G=gymnastic, C=control. The number 1,2 mean national and university team respectively.

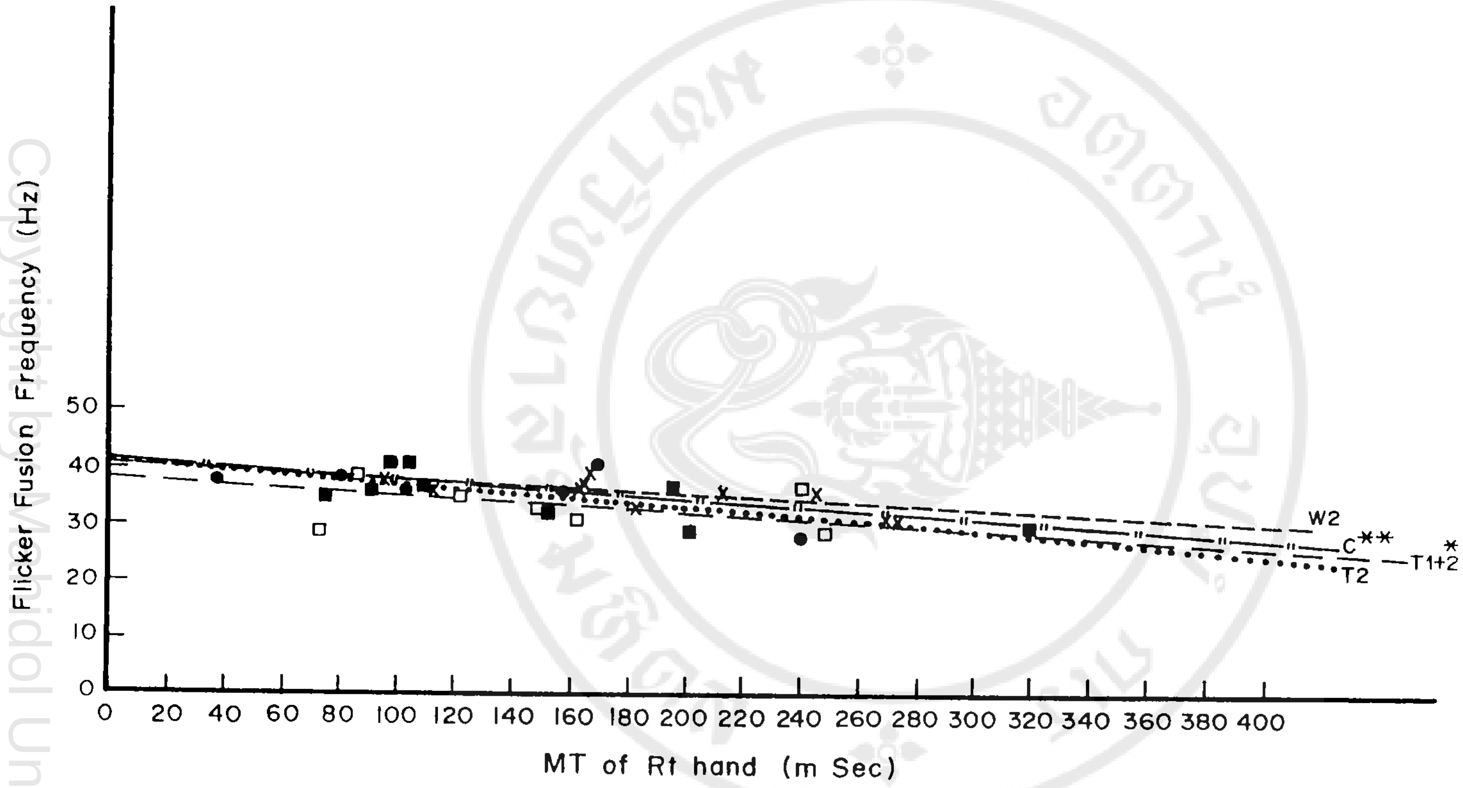


Figure 7. Correlation between flicker fusion frequency and movement time of the right hand at 0° of different sporter when W=weightlifter, T=table tennis, C=control. The number 1,2 mean national and university respectively.

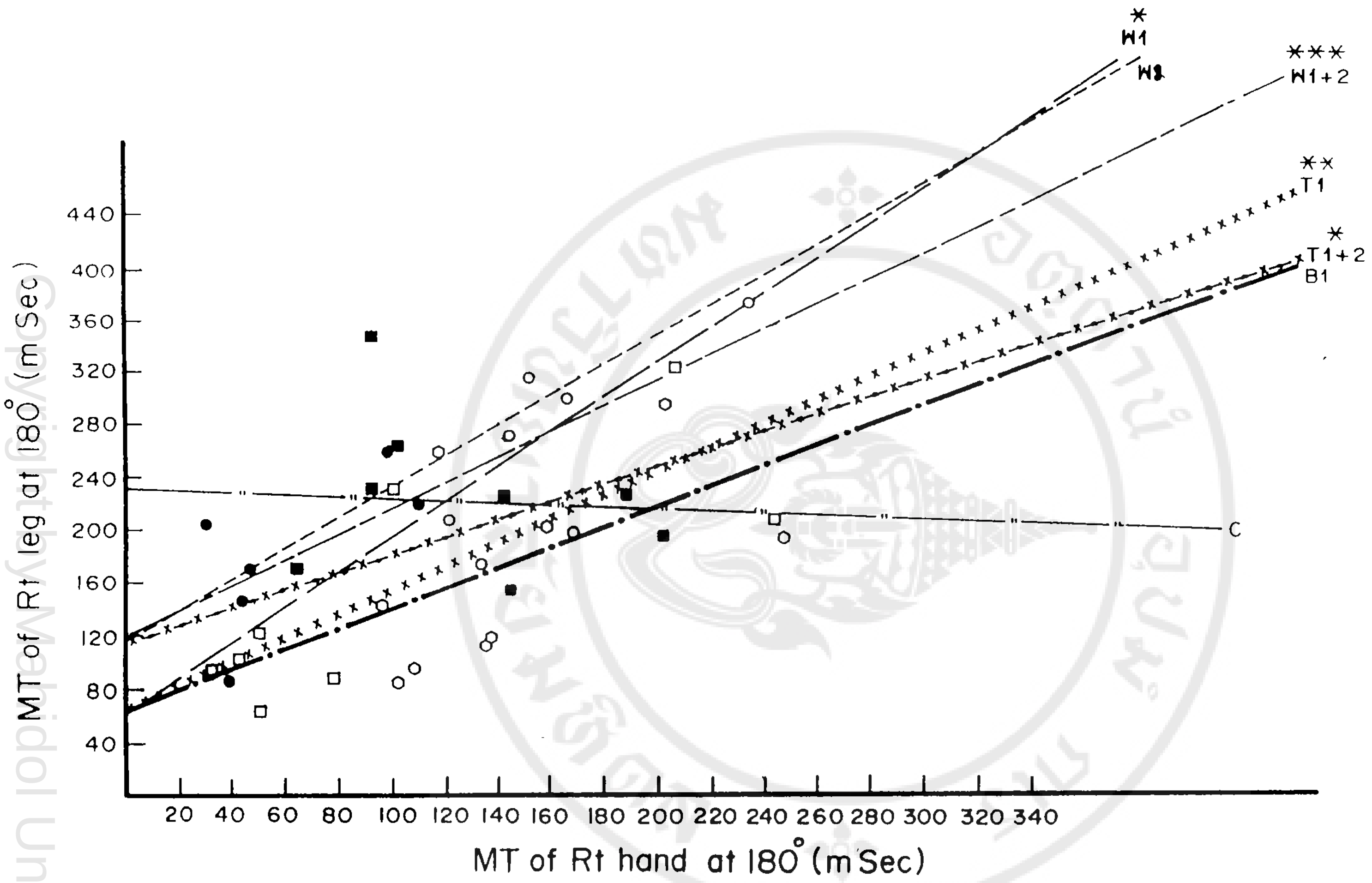


Figure 8. Correlation between movement time of the right hand and movement time of the right leg at 180° of different sporter when W=weightlifter,, B=basketball, T=table tennis, C=control, M=mixture. The number 1,2 mean national and university team respectively.

Figure 5 shows the positive correlation between non-verbal and verbal counting of weightlifter national team (W1)y=0.19+0.97x, weightlifter university team (w2)y=28.74+0.799x, gymnastic national team (G1)y=46.2+0.58x, gymastic university team (G2)y=40.75+0.72x, Gymastic both national and university team (G1+2)y=54.64+0.58x, control (c)y=26.58+0.79x, table tennis national team (T1) y=-27.58+1.25x, table tennis university team (T2)y=50.44+0.74x, table tennis both national and university team (T1+2) y=45.7+0.74x and the mixture of all of the subject (Mix) y=38.33+0.71x.

Figure 6 shows the negative correlation between verbal counting and flicker fusion frequency of weightlifter national team (W1) y=51.42-0.13x, weightlifter both national and university team (W1+2) y=47.38-0.09x.

Figure 7 shows the movement time (MT) of the right hand for the distance of 31 cm was negatively correlated with flicker fusion frequency in the weightlifter university team (W2; y=41.03 - (.036)x), table tennis university team (T2; Y=41.02-(.037)x, table tennis both national and university team (T1+2; y=38.4-(0.03)x and the control (C;y=41.41 - (.032)x). The slopes of them were nearly equal.

Fig 8 shows the movement time (MT) of the right hand at 180° direction were positively correlated with the movement time (MT) of the right leg at 180° direction in the weightlifter, gymnastic and the mixture of all the

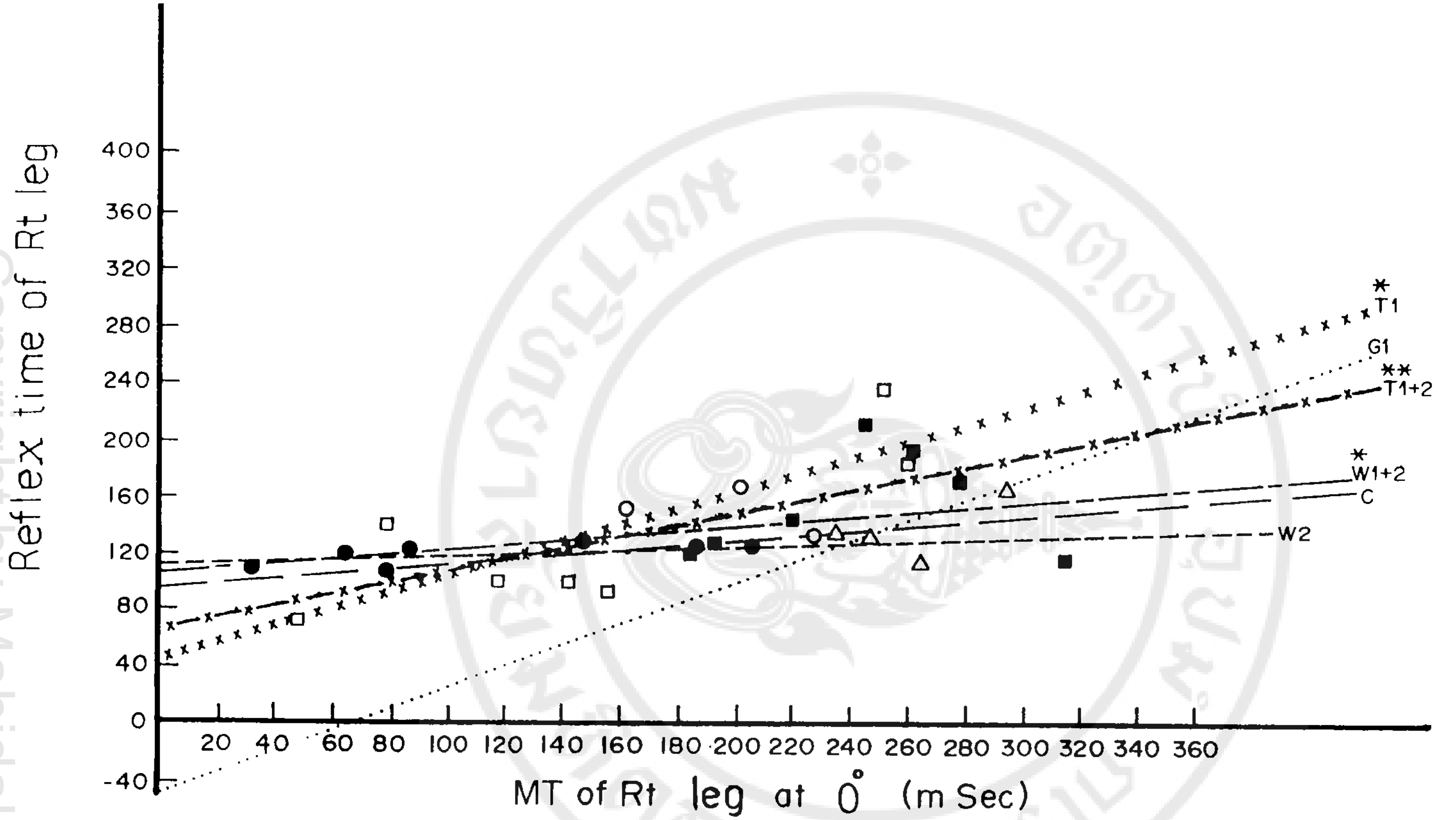


Figure 9. Correlation between movement time of the right leg at 0° and the reflex time of the right leg of different sporter when W=weightlifter, G=gymnastic, T=table tennis, C=control. The number 1,2 mean national and university team respectively.

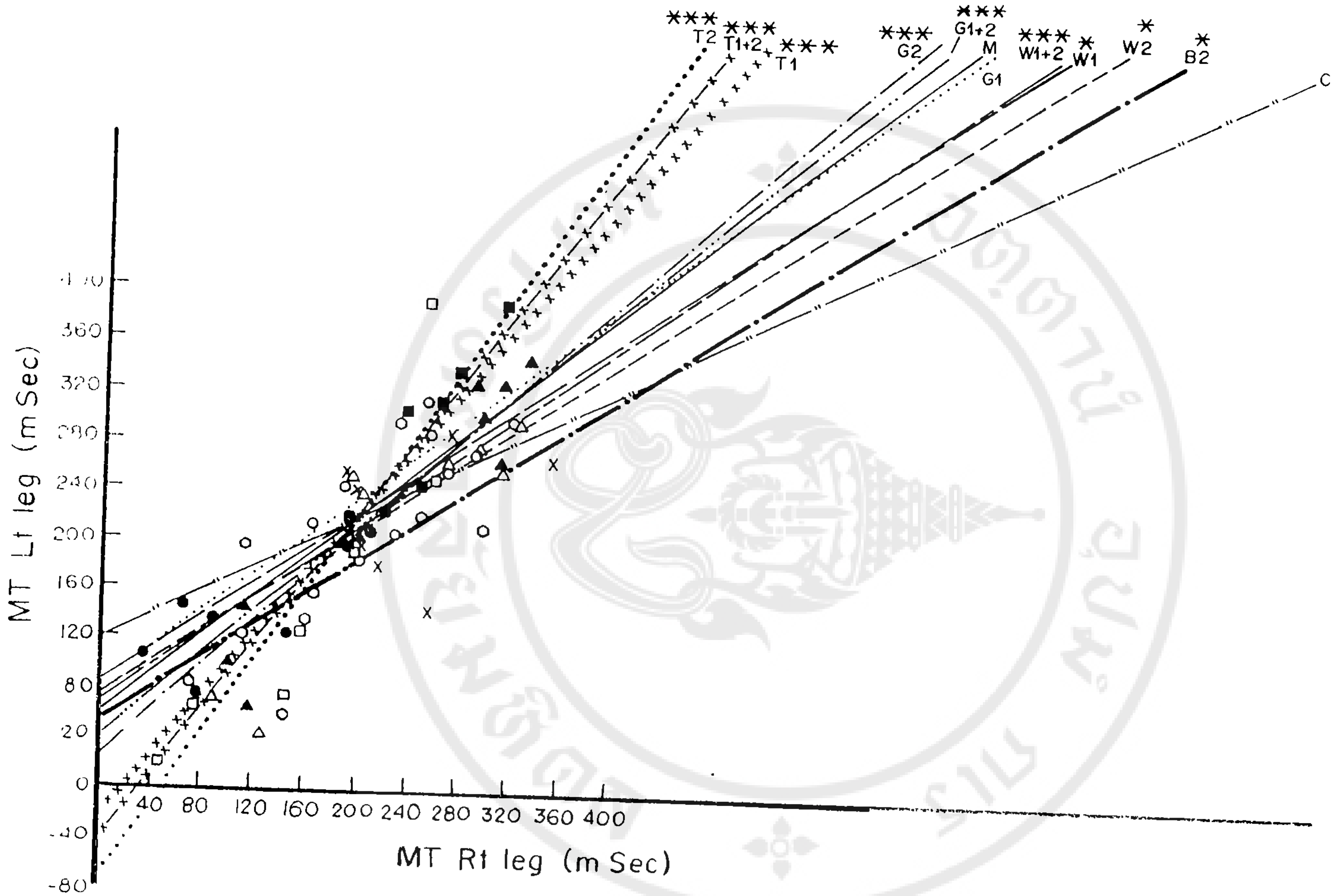


Figure 10. Correlation between movement time of the right and left leg at 0° direction (52.5 cm) of different sporter when W=weightlifter, G=gymnastic, B=basket-ball, T=table tennis, C=control, M=mixture. The number 1,2 mean national and university team respectively.

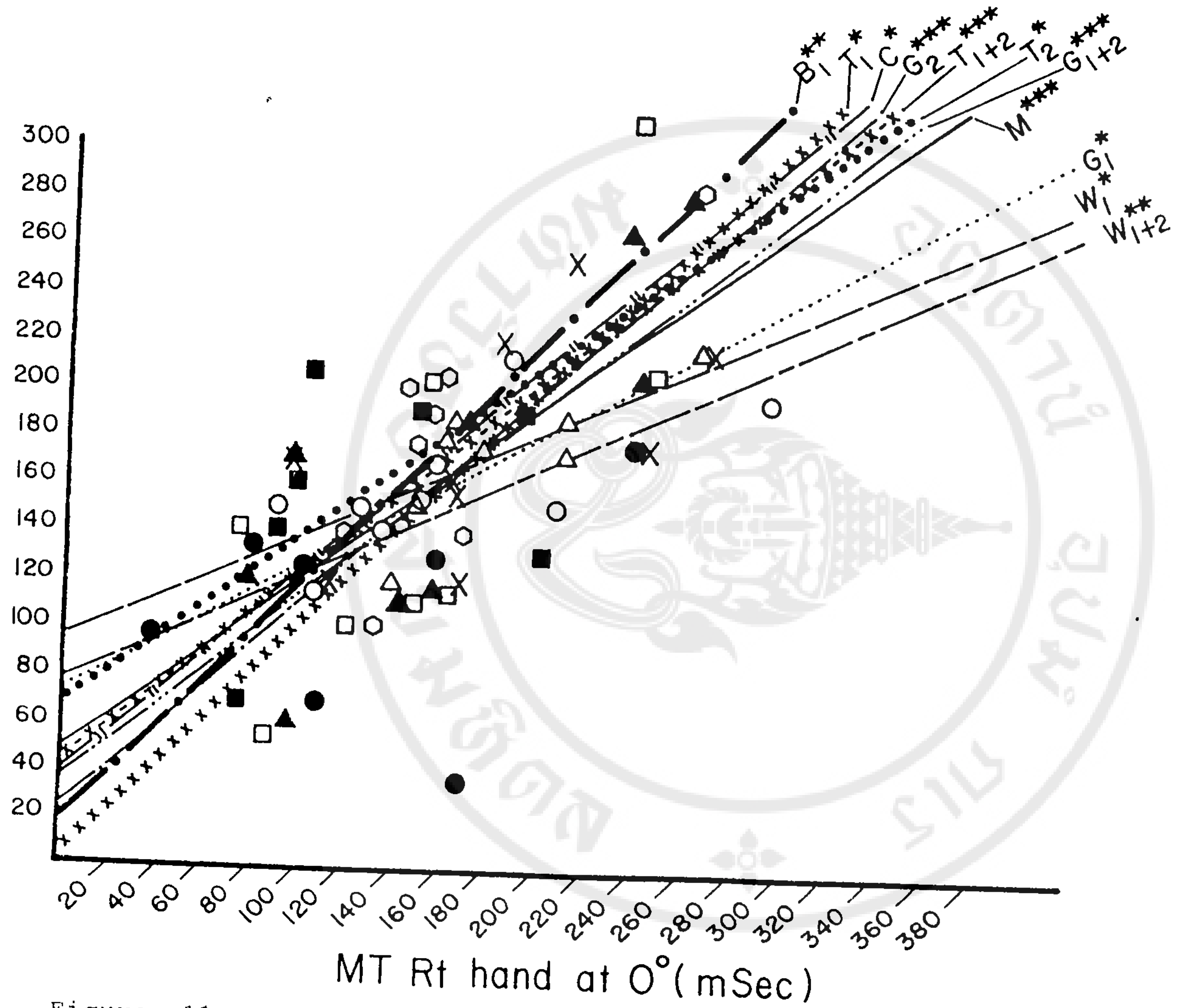


Figure 11. Correlation between movement time of the right and the left hand at 0° direction (31 cm) of different sporter when W=weightlifter, G=Gymnastic, B=Basketball, T=Table tennis, C=control, M=mixture. The number of 1,2 mean national and university team respectively.

subject. The correlation equations were y = 64.95+1.31x for W1, y=124.07+0.96 x for W1+2, y=65.15+0.89x for T1, y=115.13+0.67x for T1+2 and y=150.22+0.47x for the mixture.

Fig. 9 shows the movement time of the right leg for the distance 31 cm at 0° direction were positively correlated with the reflex time of the right leg in different sporter such as weightlifter both national and university team W1+2 (106.57+0.16x), table tennis national team (T1=44.19+0.59x), table tennis both national and university team T1+2(65.39+0.41x) and the mixture (y=109.42+0.17x).

Figure 10 shows the movement time of the right and left leg at 0° direction correlated with each other in all of sporter group. The slope of the table tennis (T1;y=-28.599+1.22x, T2;y=-75.79+1.45x,T1+2;y=-39.17+1.299 x) were more than the gymnastic (G1;y=81.04+0.72x, G2;y=25.52+0.89x, G1+2;y =40.93+0.85x), weightlifter (W1;Y=83.69+0.68x,W2;y=73.32+0.67x,W1+2;y =68.51+0.732x) and the basketball Y=53.83+0.64x). When correalated all type of sporter and the control with each other, the equation showed positive correlation between movement time of the right and the left leg at 0° direction y=58.46+0.79x.

Figure 11 shows the positive correlation between the movement time of the right and left hand for the distance 31 cm at 0° direction in all type of sporter such as weightlifter both national and university team

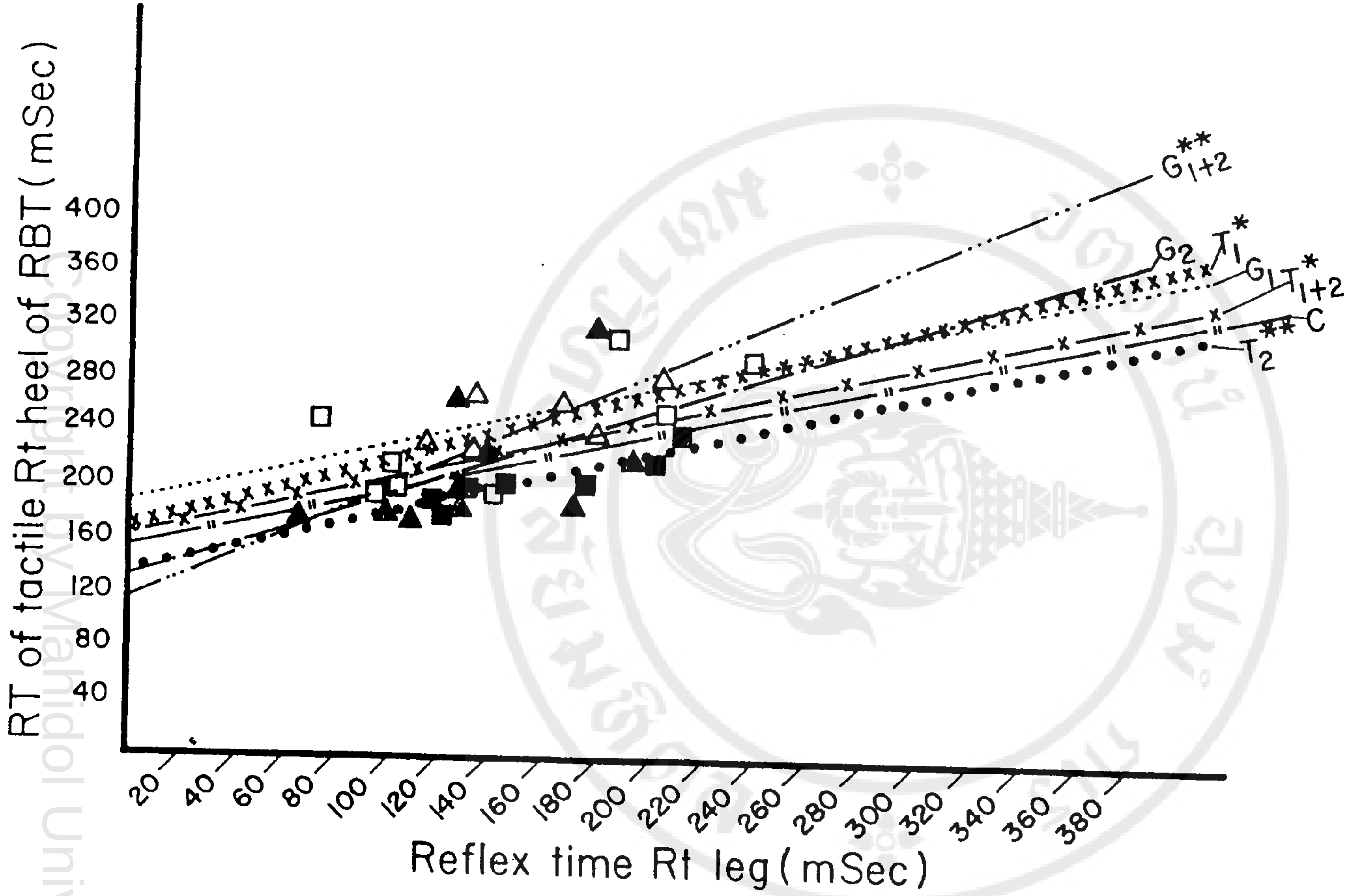


Figure 12. Correlation between patellar reflex time of the right leg and tactile reaction time of the right bigtoe when tactile stimulation was at right heel of the gymnastic (G), table tennis (T), and control (C). The number 1,2 mean national and university team respectively.

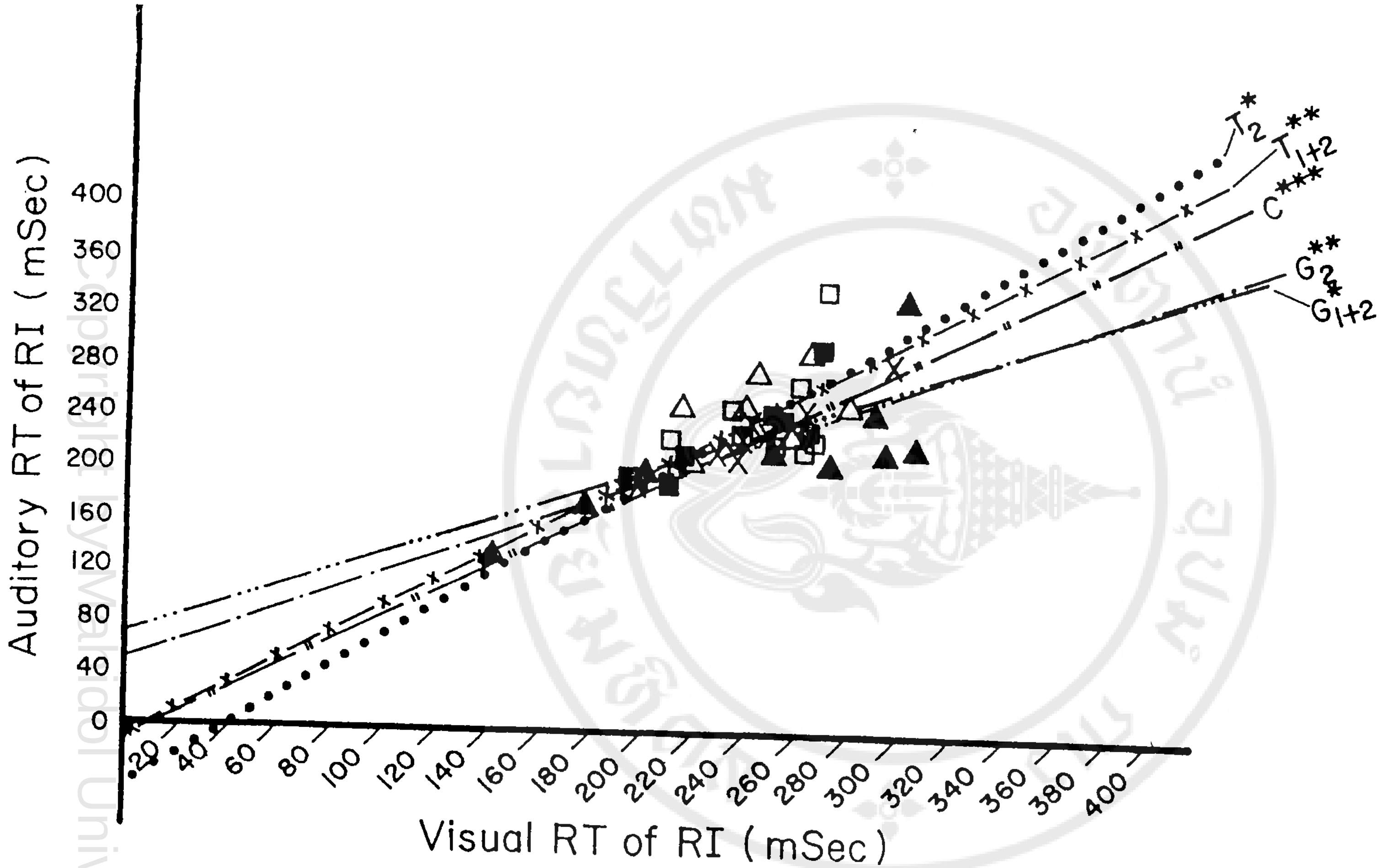


Figure 13. Correlation between visual reaction time and auditory reaction time of the right index of gymnastic (G), table tennis (T), and control (C). The number 1,2 mean national and university team respectively.

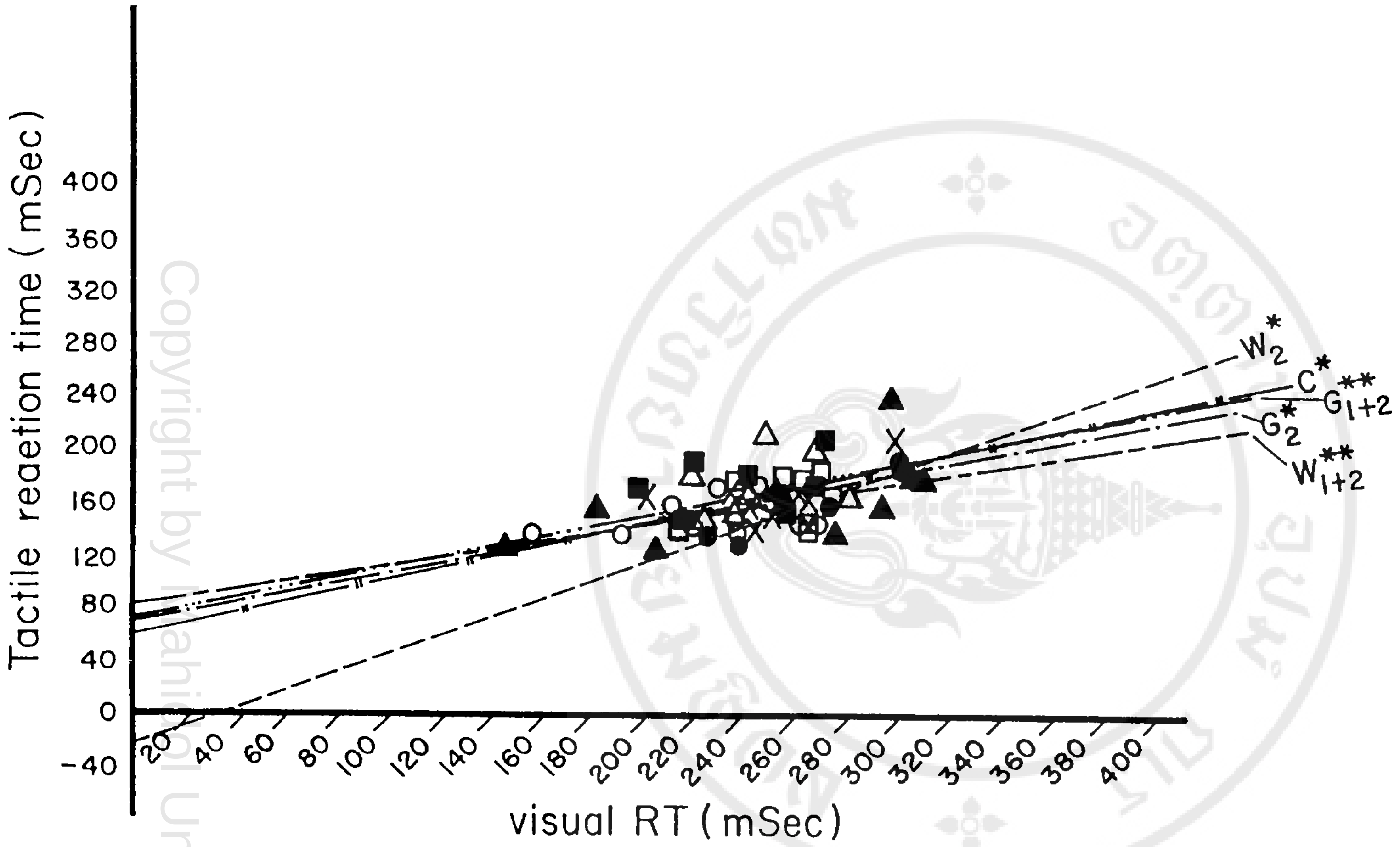


Figure 14. Correlation between visual and tactile reaction time of the right index when tactile stimulation was at acromium level of the neck of weightlifter (W), gymnastic (G), and control (C). The number 1,2 mean national and university team respectively.

(W1+2)Y=77.76+0.45x, gymnastic both national and university team (G1+2)y=37.37+0.78x, basketball national team (B1)y=19.99+0.99x, table tennis both national and university team (T1+2)y=42.02+0.81x and the control group (C) y=40.34+0.84x. When correlated all type of sporter and the control with each other, the equation showed positive correlation between the movement time of the right and the left hand y=50.77+0.72x.

Figure 12, The reflex time of the right leg showed positive correlation with the tactile reaction time of right bigtoe (RBT) when stimulated at right heel in gymnastic both national and university team (G1+2)y=136.12+0.66x, and the table tennis both national and university team (T1+2)y=159.17+0.44x.

The positive correlation between visual reaction time of the right index and the auditory reaction time of the right index of gymnastic both national and university team, table tennis both national and university team and the control were showen in Fig. 13. The equation correlation were y=77.33+0.66x for G1+2, y=-11.986+1.03x for T1+2, and y=-10.58+0.98x for the control group.

Figure 14 shows the positive correlation between the visual reaction time of the right index and the tactile reaction time of the right index when stimulated at acromium level of the neck in the weightlifter both national and university team (w1+2)y=81.65+0.301x, gymnastic both nationnal and university team

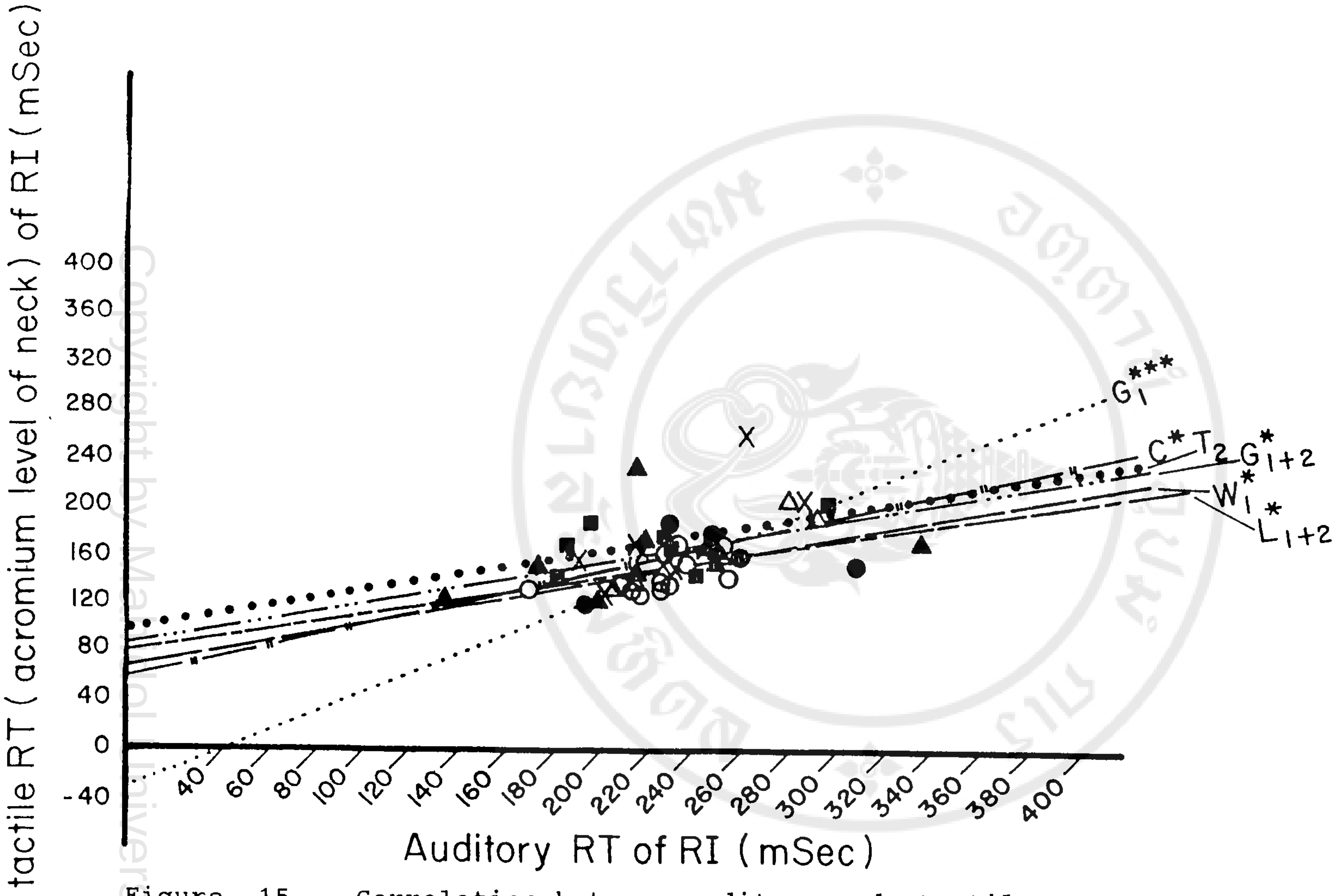


Figure 15. Correlation between auditory and tactile reaction time of the right index when tactile stimulation was at acroium level of the neck in different sporter when W=weightlifter, G=gymnastic, T=table tennis, c=control. The number 1,2 mean national and university team respectively.

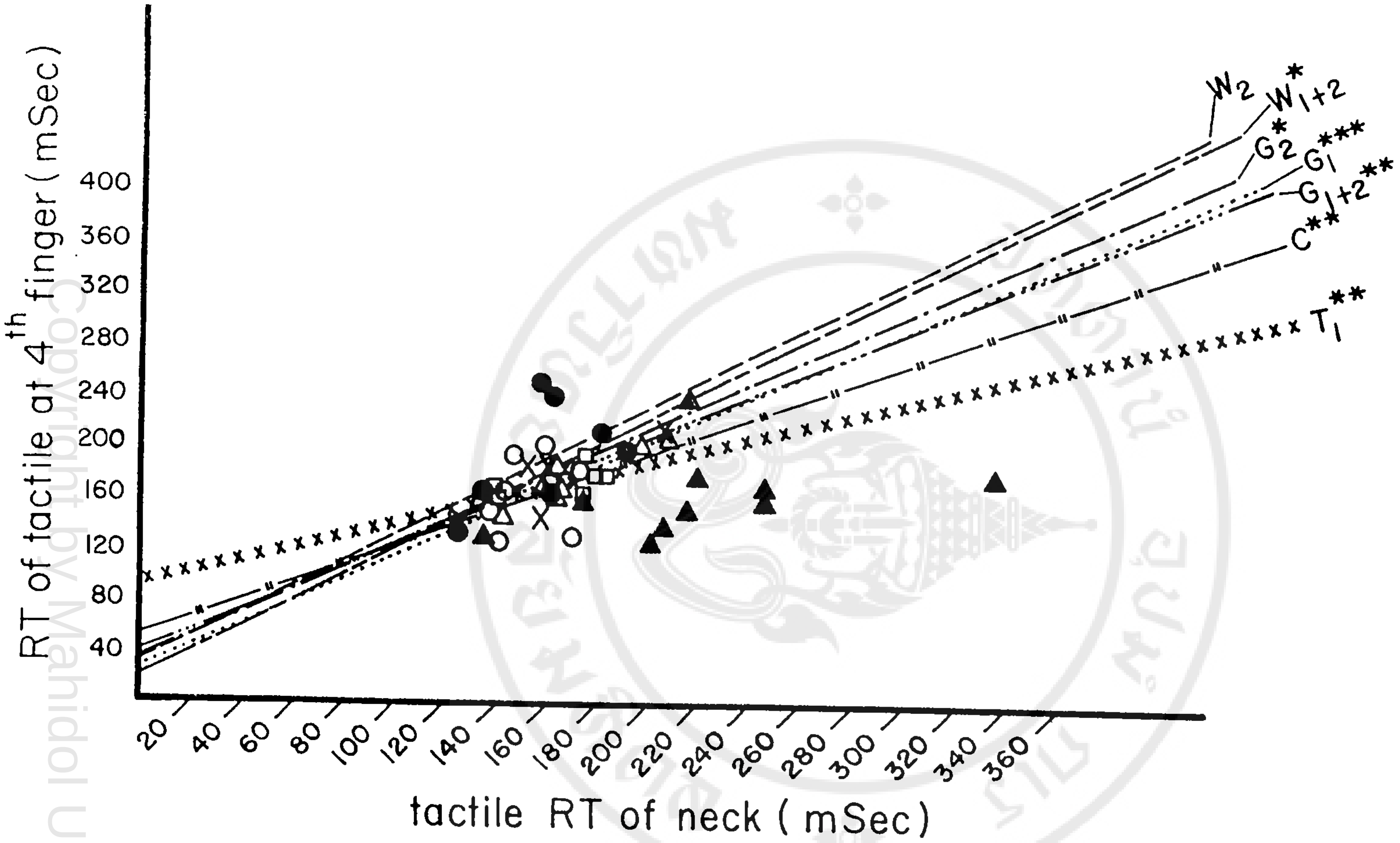


Figure 16. Correlation between tactile reaction time of the right index when tactile stimulation was at acromium level of the neck and at the right 4th finger in different sporter when W=weightlifter, G=gymnastic, T=table tenis. The number 1,2 mean national and university team respectively.

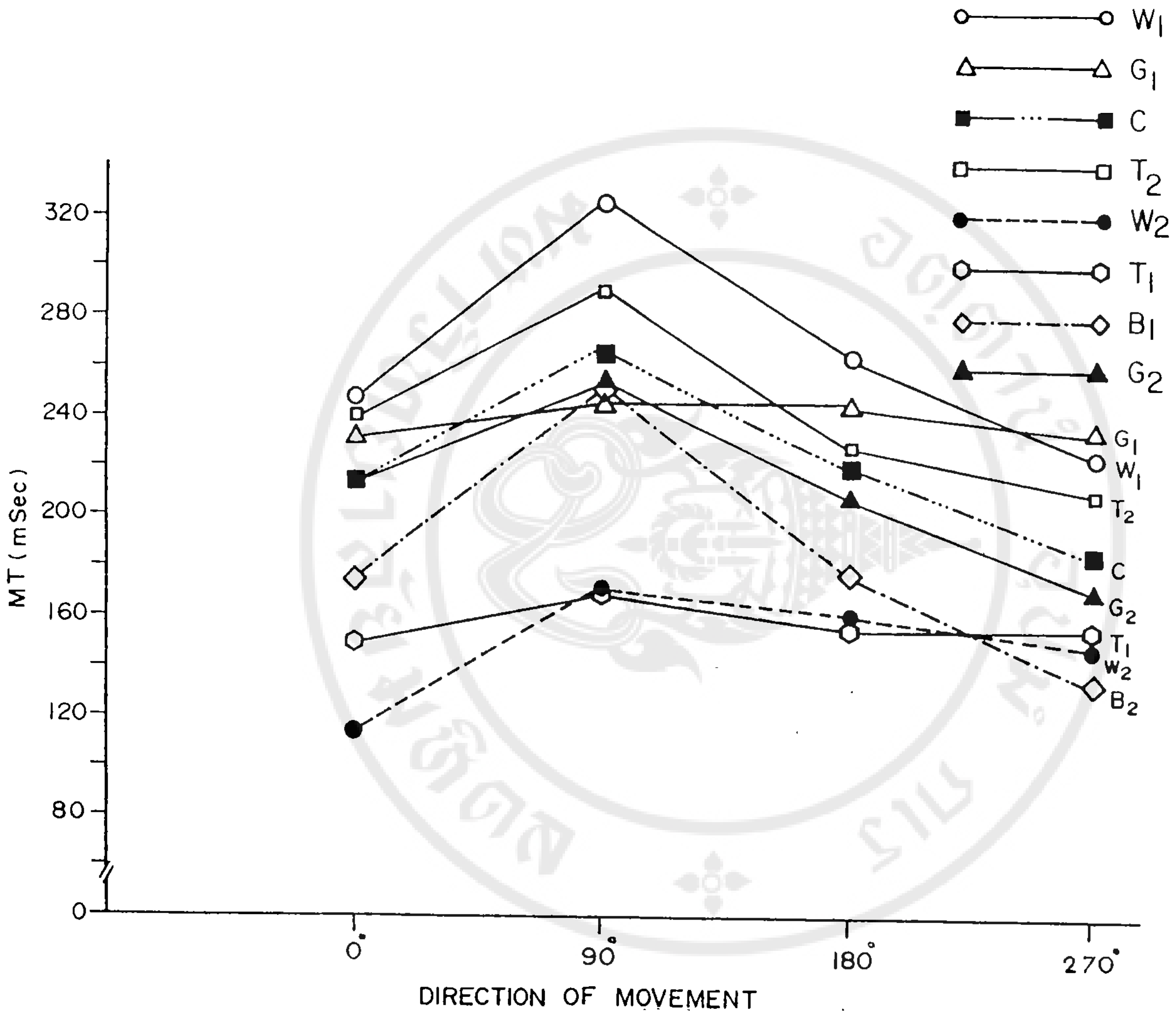


Figure 17. Movement time of the right leg when the distance was 52.5 cm in different direction of movement 0°, 90°, 180° and 270° of different sporter when W=weightlifter,G=gymnastic, B=basketball, T=table tennis, C=control. The number 1,2 mean national and university team respectively.

(G1+2)$y=74.77+0.368x$, and the control group (C) $Y=60.54+0.42x$.

The positive correlation between auditory reaction time and tactile reaction time when stimulated at acromium level of the neck of different sporter were presented in the Fig. 15. The correlation equation of weightlifter national team (W1) was $y=68.98+0.35x$, gymnastic national team (G1)$=-30.38+0.795x$, gymnastic national and university team (G1+2)$y=89.36+0.325x$, table tennis university team (T2)$y=99.096+0.33x$ and the control group $y=159.19+0.45x$.

Figure 16 shows the positive correlation between tactile reaction time of the right index when stimulated at acromium level of the neck C7 and at the right 4th finger of weightlifter national and university team (W1+2)$y=19.22+1x$, gymnastic national and university team (G1+2)$y=38.97+0.84x$, table tenis national team (T1)$y=91.31+0.48x$ and the control group (C) $y=54.77+0.71x$.

Figure 17 shows the movement time of the right leg for distance 52.5 cm at 90° direction (cross-body) of all type of sporter. The movement time of the right leg at 0° (forward) and 180° (backward) were nearly equal. The movement time of the right leg at 270° (the right side) were shortest than other direction.

Figure 18 shows the movement time of the right leg at 0° of weightlifter national team (W1=247.76±17.9 msec) was significantly longer than basketball national team (B1=174.41±25.73 msec), table tennis national team (T1=150.09±28.5 msec). The movement time of gymnastic

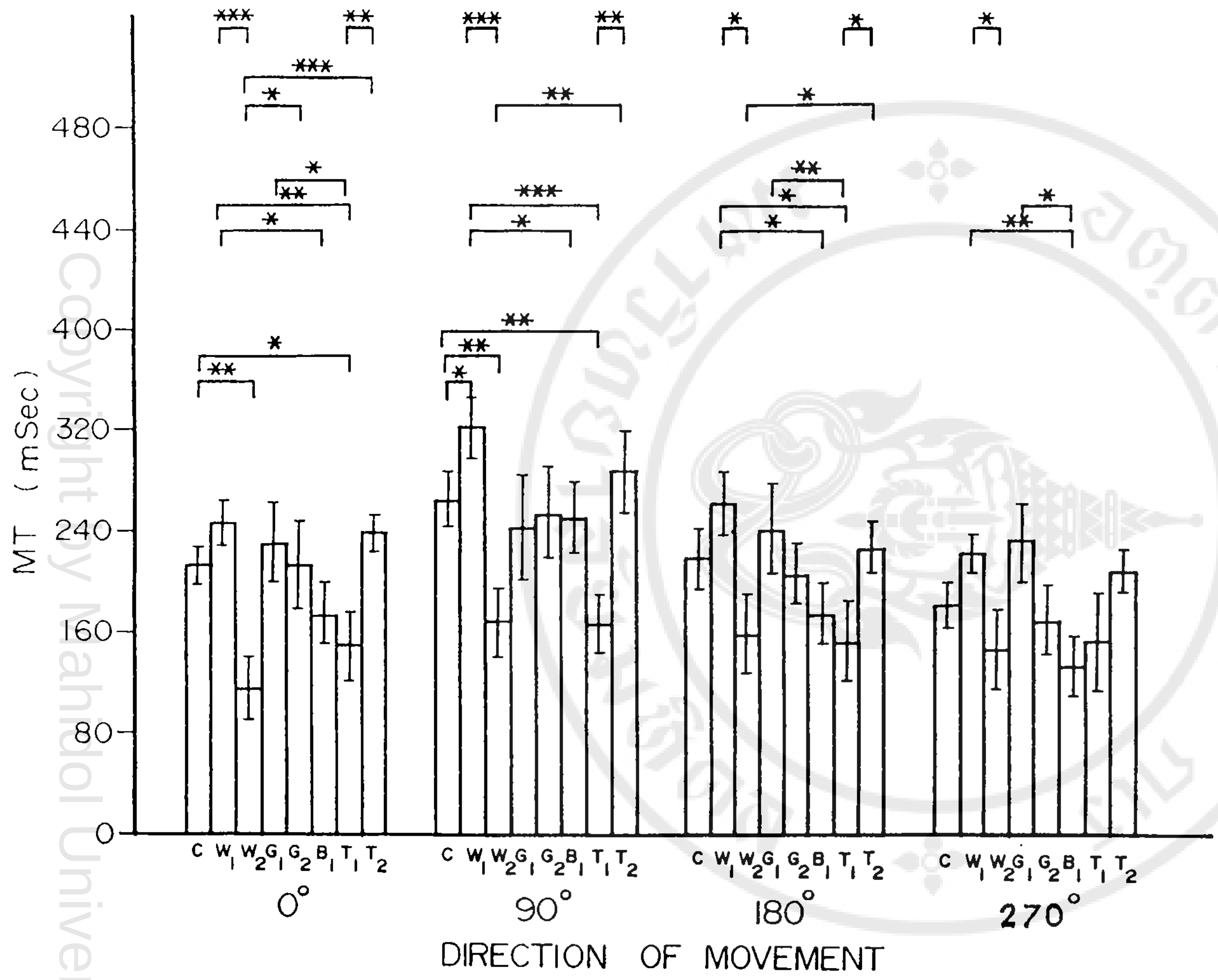


Figure 18. Histogram indicating the mean values in msec of movement time of right leg at different direction 0°, 90°, 180°, 270° (52.5 cm) of different sporter when W=weightlifter, G=gymnastic, B=basketball, T=table tennis, C=control. The number 1,2 mean national and university team respectively.

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national team (G1=230.86±32 msec) was nearly equal to the movement time of W1 and significantly longer than T1. When compare between university team the opposite result was found. The movement time of the weightlifter university team (W2=115.0±25.29 msec) was significantly shorter than gymnastic university team (G2=213.79±35.21 msec), table tennis university team (T2=241.53±15.41 msec) and the control (C=214.51±14.53 msec).

The movement time of the right leg at 90° of weightlifter national team (325.01±25.8 msec) was significantly longer than basketball national team (B1=251.94±28.7 msec), table tennis national team (T1=168.7±25.4 msec) and the control group (C=265.9± 22.06 msec), but when compare between university team the movement time of weightlifter (W2=169.96±27.97 msec) was significantly shorter than T2 (290.53±33.52 msec) and the control (C=265.9±22.06 msec).

The movement time of the right leg at 180° of W1(263.65±26 msec) was significantly longer than B1(177.44±24.13 msec), T1 (154.9±32.3 msec) and that of G1(244.23±35.96 msec) was significantly longer than T1 but not significantly longer than B1.

The movement time of the right leg at 270° of B1 (134.73±25.4 msec) was significantly shorter than W1 (224.46±14.6 msec), and G1 (234.49±31.6 msec). In the university team didn't show significantly different.

The movement time of the right leg in weightlifter naional team (W1) were longer than university team (W2) in

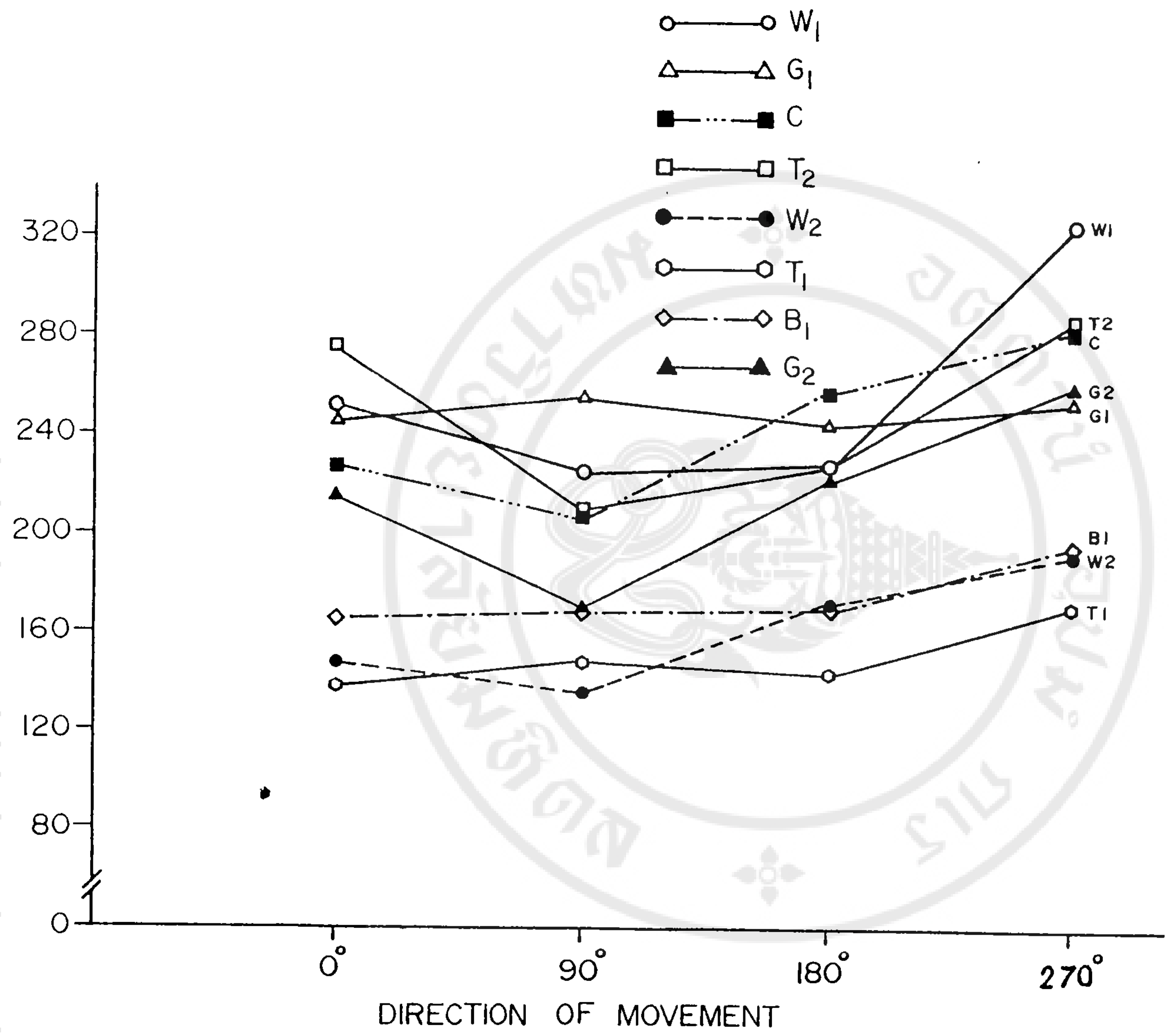

Figure 19. Movement time of the left leg at different direction 0°, 90°, 180°, 270° (52.5 cm) of different sporter. W=weightlifter, G=gymnastic, B=Basketball, T=table tennis, C=control. The number 1,2 mean national and university team respectively.

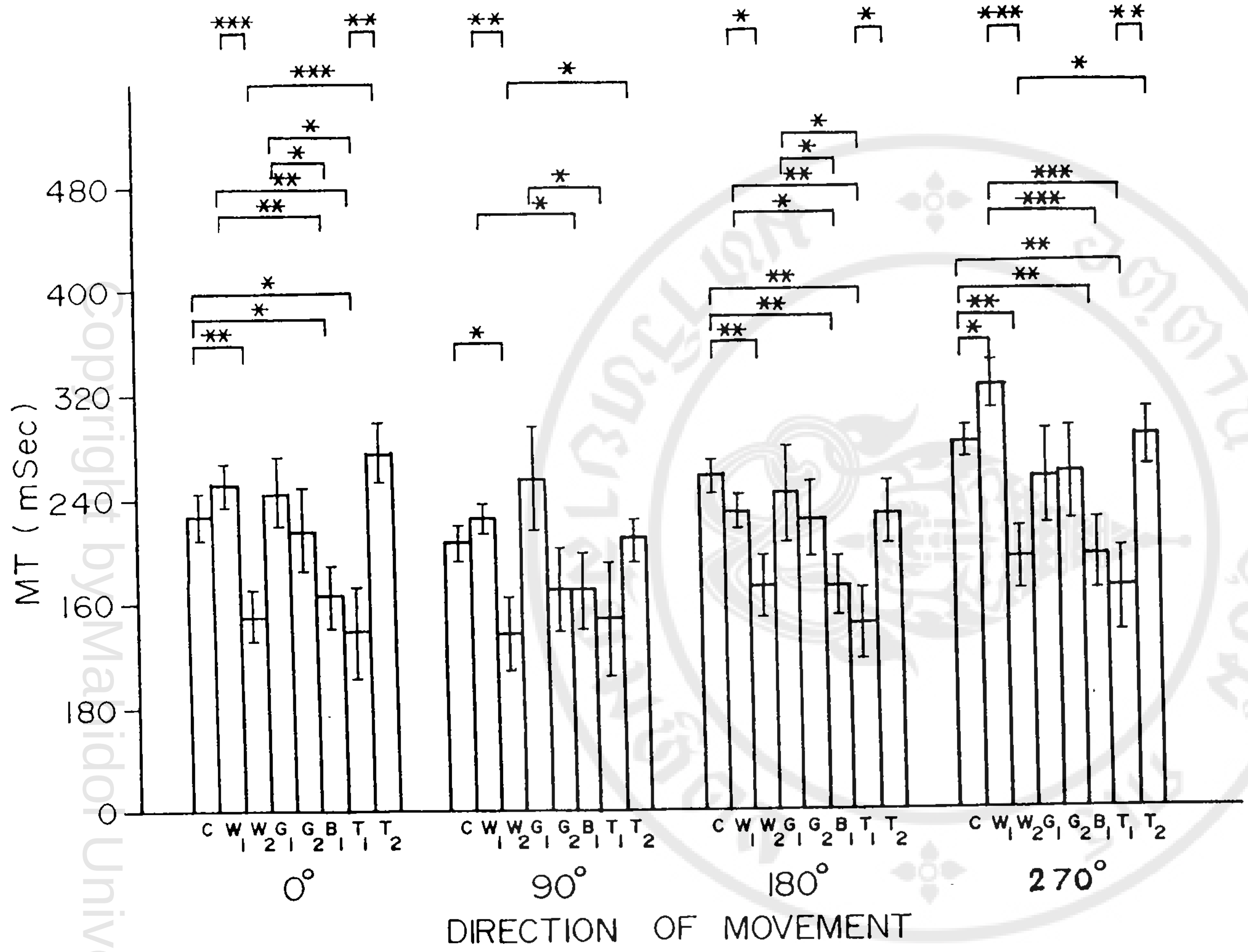

Figure 20. Histogram indicating the mean values (+SEM) in msec of movement time of the left leg when the distance was 52.5 cm of different direction and different sporter W=weightlifter, G=gymnastic, B=basketball, T=table tennis, C=control. The number 1,2 mean national and university team respectively.

all direction of movement. The opposite results were found in the table tennis national team in all direction of movement except at 270° direction (national team less than the university team).

The movement time of different sporters were shown in different directions of movement. The movement time of the left leg to the opposite side of the body (270°) were the longest in all type of sport. The movement time of the left leg at 0°, 90°, 180° were nearly equal (Fig. 19). The mean in msec of movement time of the left leg at different directions were shown in Fig. 20.

The movement time at 0° direction of the basketball national team (B1=166.01±24.47 msec) was nearly equal with table tennis national team (T1=138.6±37.8 msec) which were significantly shorter than weightlifter national team (W1=252.55±16.75 msec), gymnastic national team (G1=246.34±27.96 msec) and the control group (C=228.17±17.69 msec) when compare between university team, the movement time of W2 (149.8±21.62 msec) was significantly shorter than T2 (275.96±23.96 msec).

The movement time of the left leg at 90° direction of the basketball national team (B1=170.43±26.45 msec) and table tennis national team (T1=148.2±43.7 msec) were significantly shorter than weightlifter national team (W1=226.45±10.81 msec) and no significantly shorter than the control group (C=207.15±13.8 msec). The movement time in gymnastic national team (G1) was significantly longer than T1 but wasn't significantly longer than B1 and C.

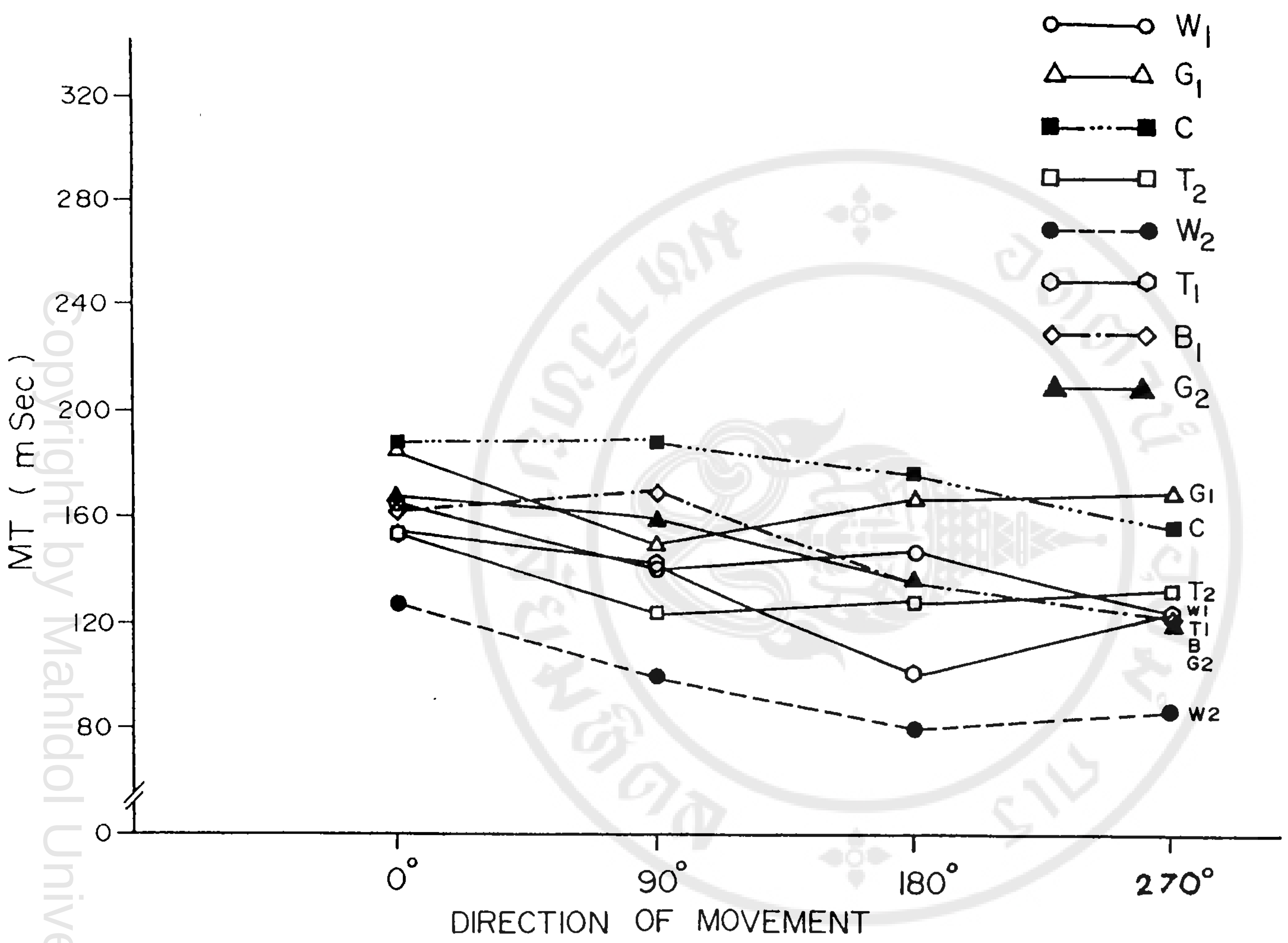

Figure 21. Movement time of the right hand at different direction 0°, 90°, 180° and 270° (31 cm) of different sporter when W=weightlifter, G=gymnastic, B=basketball, T=table tennis, C=control. The number 1,2 mean national and university team respectively.

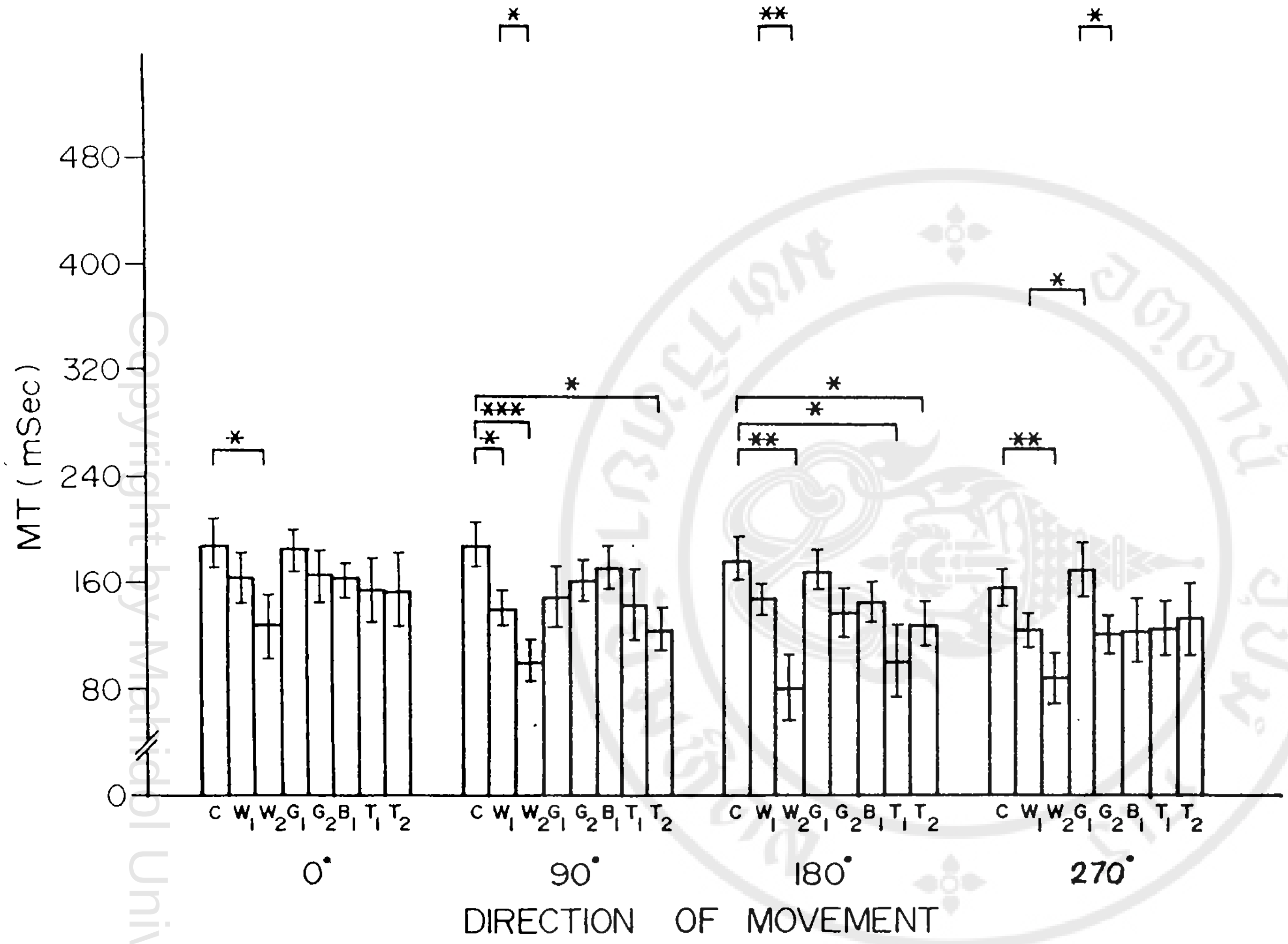

Figure 22. Histogram indicating the mean values (+SEM) in msec of movement time of the right hand when the distance was 31 cm and direction is 0°, 90°, 180°, 270° of different sporter W=weightlifter, G=gymnastic, B=basketball, T=table tennis, C=control. The number 1,2 mean national and university team respectively.

The movement time of the left leg at 180° of both B1 (171.73±22.99 msec) and T1 (144.5±29.1 msec) were significantly shorter than W1 (230.78±13.18 msec), G1 (245.49±36.2 msec) and the control (C=258.66±14.37 msec).

The movement time of the left leg at 270° of both B1 (195.18±29.16 msec) and T1 (171.5±33.2 msec) were significantly shorter than W1 (326.31±18.7 msec) and the control (C=282.53±12.82 msec). When compare in the university group showed the movement time of the table tennis university team (T2=287.14±24.20 msec) longer than weightlifter university team (W2=194.49±25.31 msec). The movement time of the left leg of weightlifter national team (W1) were significantly longer than weightlifter university team (W2) in all directions of movement but the movement time of the table tennis national team (T1) were significantly shorter than university team (T2) in all directions of movement except at 90° direction.

Figure 21 shows that movement time of the right hand at 270° direction were shorter than other directions (0,90,180°). The movement time of the right hand to the opposite side of the body (90°) were not longer than forward direction (0°) which different from the pattern of the leg.

Figure 22, The movement time of the right hand of different sporter were not significantly different from each other in all directions except the movement time of the gymnastic national team (G1=169.54±21.7 msec) at 270°

was significantly longer than weightlifter national team (W1=125.05±13.4 msec).

When compare with the control group it was found that the movement time of the right hand of weightlifter university (W2) were shorter than the control in all directions (0° ; C=188.71±19.34 msec, W2=127.6±25.28 msec, 90° ; C=188.74±18.54 msec, W2=100.59±17.61 msec, 180° ; C=176.38±17.31 msec, W2=280.94±23.3 msec,270° C=155.68±14.3 msec, W2=87.37±20.97 msec).

The movement time of other sporter didn't significantly shorter than the control except W1 (140.4±14.4 msec) was significantly shorter than C (188.74±18.50 msec) at 90°, table tennis national team (T1=100.3±28.4 msec) and university team (T2=128.26±17.28 msec) were significantly shorter than the control (C=176.38±17.31 msec) at 180° direction.

The movement time of the right hand of the weightlifter national team (W1) were significantly longer than weightlifter university team (W2) at 90° direction (W1=140.4±14.4 msec, W2=100.59±17.61 msec) and at 180° direction (W1=147.02±12 msec, W2=80.94±23.3 msec).

The movement time of the right hand of gymnastic national team (G1=169.54±21.7 msec) was longer than university team (G2=119.76±14.6 msec).

Figure 23 shows the movement time of the left hand at opposite side of the body(270°) were nearly equal to at 0° direction (forward) and were a little longer than the movement time at 90° and 180° (back ward).

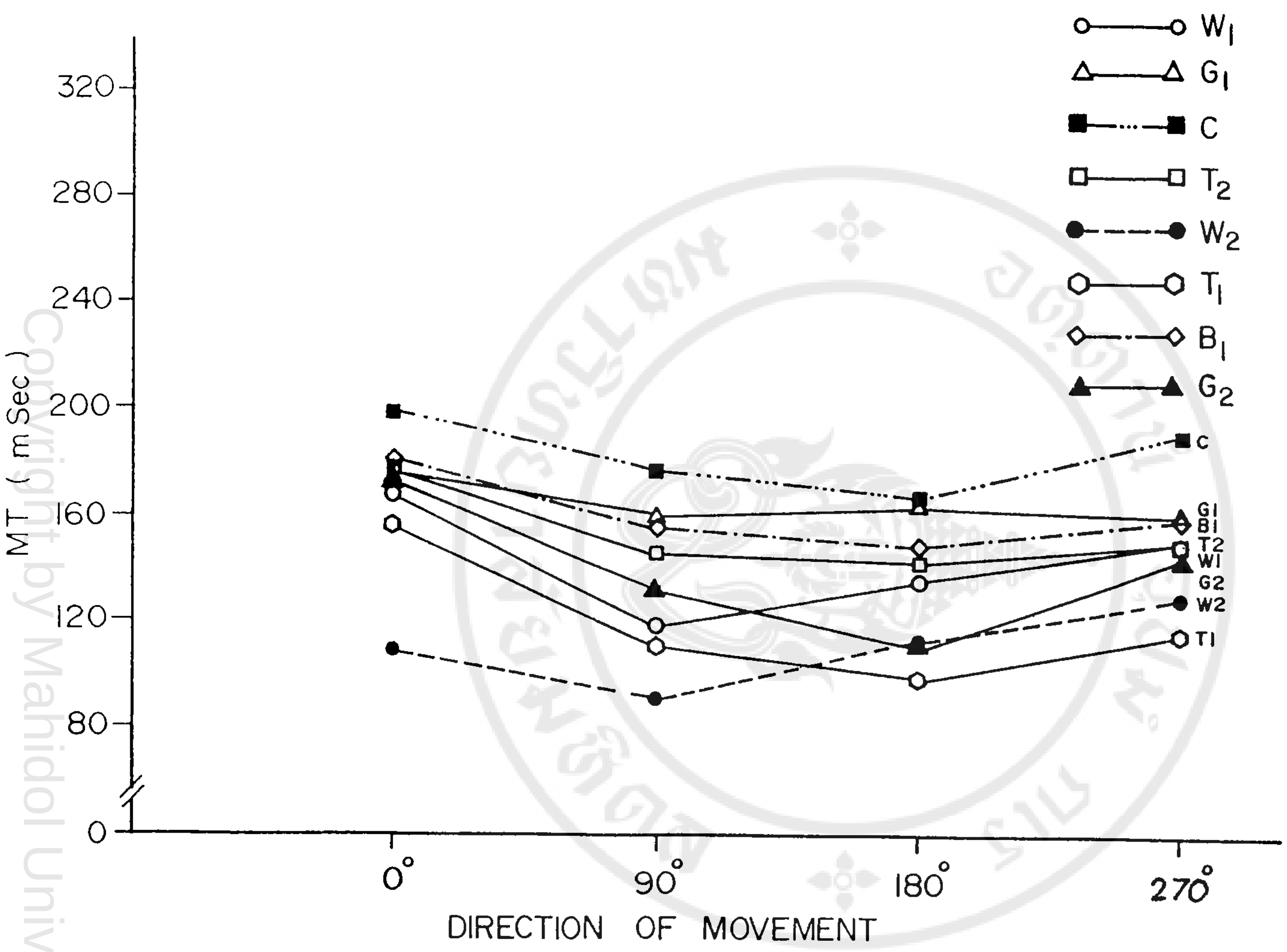

Figure 23. Movement time of the left hand at different direction 0°, 90°, 180°, 270° (31 cm) of different sporter W=weightlifter, G=gymnastic, B=basketabll, T=table tenis, C=control. The nummber 1,2 mean national and university team respectively.

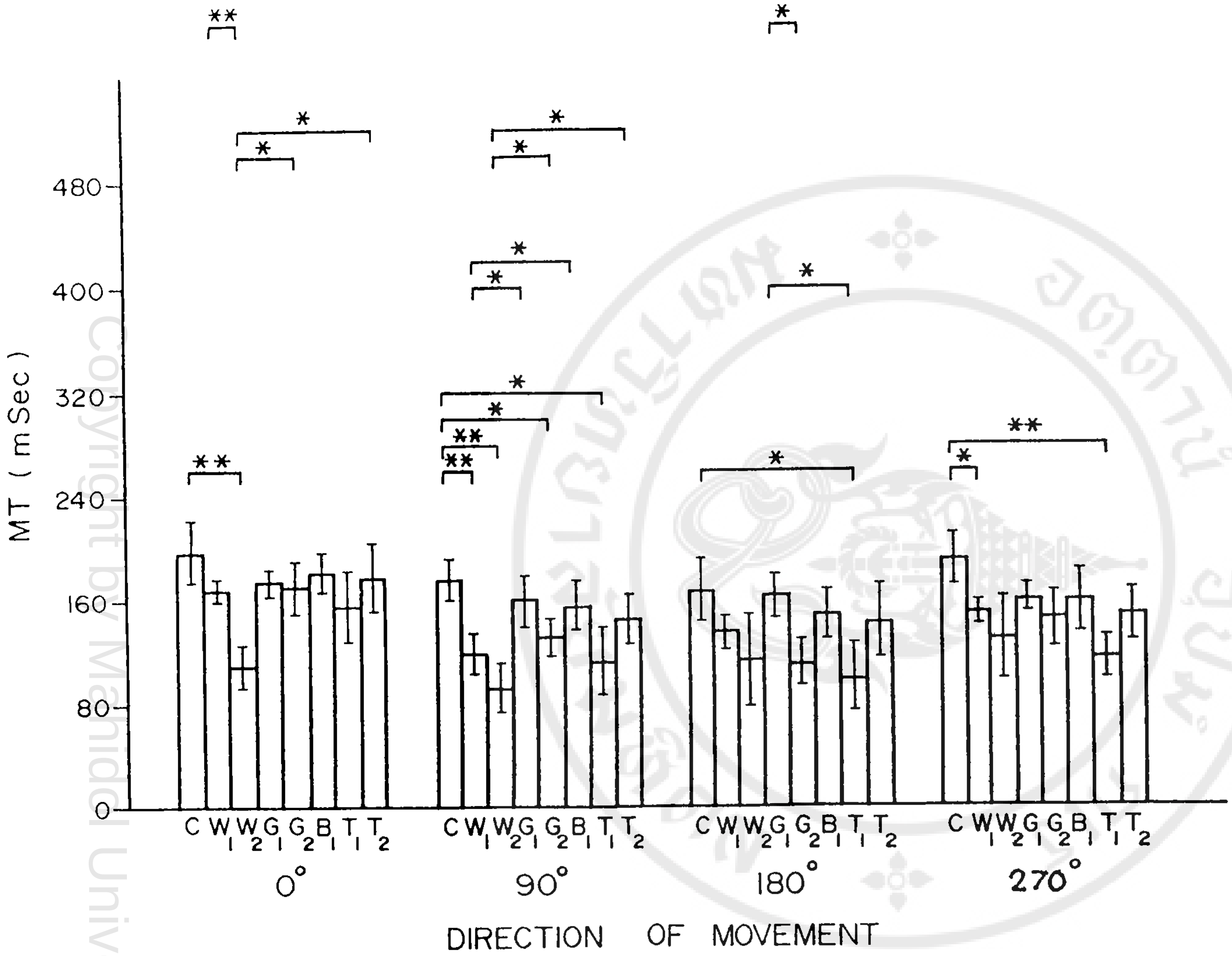

Figure 24. Histogram indicating the mean values in msec of movement time of the left hand when the distance was 31 cm and direction was 0°, 90°, 180°, 270°. The abbreviation are W=weightlifter, G=gymnastic, B=basketball, T=table tennis, C=control. The number 1,2 mean national and university team respectively.

Figure 24, The movement time of the left hand at 0° direction of national sporter were not significantly different from each other but the movement time of weightlifter of university team (W2=110.89±17.57 msec) was significantly shorter than gymnastic university team (G2=171.07±21.98 msec), table tennis university team (T2=178.54±26.61 msec), the control group (C=198.09±23.64 msec) and weightlifter national team (W1=168.17±10.9 msec).

The movement time of the left hand at 90° of the weightlifter national team (W1=119.44±9.6 msec) was significantly shorter than the gymnastic national team (G1=160.4±20 msec), basketball national team (B1=157.37±18.13 msec) and the control group (C=177.63±17.41 msec). The last, the movement time of the table tennis national team (T1=112.2±26.25 msec) was significantly shorter than C and no significant different between G1 and B1. In the university group, the movement time of weightlifter (W2=92.20±18.42 msec) was significantly shorter than gymnastic (G2=133.88±14.97 msec), table tennis (T2=146.53±21.83 msec) and the control (C=177.63±17.41 msec).

The movement time of the left hand at 180° of the table tennis national team (T1=99.0±26.3 msec) was significantly shorter than gymnastic national team (G1=163.67±17.7 msec) and the control (C=167.04±25.3 msec) but was not significantly shorter than weightlifter national team (W1=136.61±11.6 msec) and basketball national team (B1=149.24±19.72 msec). There was no significant difference between different university groups.

The movement time of the left hand at 270° of the control (C=191.76±20.66 msec) was significantly longer than the table tennis national team (T1=116.98±16.4 msec) and the weightlifter national team (W1=149.49±10.6 msec). There was no significant difference between national and university group.

CHAPTER VI

DISCUSSION

The hand grip strength of weightlifter national team was highest and significantly greater than that of the control, the gymnastic national team and the weightlifter university team. The leg strength of the weightlifter national team was also highest. Whereas the relative grip strength of the weightlifter national team was lowest but the relative leg strength wasn't. The reaction time task, the reaction time of the weightlifter national team also showed fastest. Then the relation between the reaction time and the strength were analized. The result didn't show significant correlation. In addition, the relative strength of the weightlifter national team was lower than the weightlifter university team. Therefore, it may be interpreted that the faster of the reaction in the weightlifter national team may be not due to the strength of the muscle.

The maximal oxygen uptake is an indicator which define the maximum aerobic power of the subject during exercise. The higher the oxygen uptake, the higher the energy aerobic output. The maximum oxygen uptake can be improved with training. The training in the more intensive, the more frequency, and the longer the training program, the greater will be the fitness benefits. (Fox 1984, Astrand 1977, 1986). The present result also shows that the maximal oxygen uptake of gymnastic,basketball and table tennis national team are significantly greater than the sedentary (the control group). Again the duration of training program can affect the maximal oxygen uptake, so the gymnastic and the table tennis national team showed significantly higher than gymnatic and table tennis university team who had trained for a short period. The weightlifter group had lower maximal oxygen uptake when compare with the gymnastic, basketball and table tennis national team. It might be due that the weightlifters had less aerobic training and use shorter duration of muscle use during training when compare with other sporters.

Flexibility depends on the extent of mobility in the joints, but can be improved by training (Henatsch and Langer 1985). Fox (1984) mentioned that streching exercise can increase flexibility. It was shown that training causes a hypertrophy of the intercellular substance of connective tissue, increasing the volume of tendons and ligaments and enhances their tensile strength (Astrand 1977). The flexibility in the present result showed highest in the gymnastic national team. This may be due to streching exercise in their trainig program of gymnastic. From the result, not only the flexibility but also balance was highest in the gymnastic national team. The balance of weightlifter, gymnastic, table tennis were also higher than control group. The study of Fiebert and Brown (1979) showed that 12 weeks of aerobic activity and streching exercise in elderly persons can improve balance. The increase of balance may be partly due to the increasing of aerobic and anaerobic capacities. (Eva and Hikkinen 1985, Robert 1989). It has been shown that the physical activity can also increase flexibility and muscle strength and these changes may account for the improvement in balance (Robert 1989).

The electromyographically (EMG) recording can fractionated the reaction time into two components; premotor time (PMT) which represent central effect and contraction time (CT) or motor time (MT) which represents peripheral effect (Botwinick & Thomson 1966). Both PMT and CT can be effected by activity level. (Craymer et al 1990, Dustman et al 1984, Baylor and Spirduso 1988). Hascelik also show the lesser reaction time in trained subject than untrained subject (Hascelik, et al 1989). In the present study,the result shows lesser in the reaction time of the weightlifter national team (W1) than the other types of sports and the control group. It can assume that the different program and method of training can affect the reaction time both in central and peripheral pathway. In peripheral pathway, the lesser reaction time of weightlifter may be due to the higher percentage of fast twitch fibers. The strength training in the weightlifter group was shown to enhance the hypertrophy of the muscle with selective fast twitch hypertrophy (Saltin 1977, Tesch, et al 1984, 1985, Hakkinen, et al 1985, Johnson and Edgley 1991). The time required for the fast twitch fibers to generate maximal tension is about one third that required by slow twitch fibers. Larsson (1978) reported the significant positive correlation between the percentage of number of type II and nerve conduction velocity (Larsson 1978). The reason for the faster contraction time in fast twitch fibers are

a) greater anaerobic capacity (Fox 1984)

b) the size of the motorneuron that innervates the fast twitch unit. The motor neuron innervating the fast twitch unit is larger than the motorneuron in the slow twitch (Fox 1984). The terminal on the fast gastrocnemius muscle fibers were more wide spreading, long and smooth and more acetylcholinesterase is found in fast twitch than in slow twitch fibers (Nystrom 1968). Kuno also found the direct correlation between end-plate potential frequency and the end plate size (Kuno, et al 1971)

c) less time taken for the contractile component to stretch the elastic component which Viitasalo showed the relation between the shorter of electromechanical delay (EMD) and the higher fast twitch fibers composition (Viitasalo and Komi 1981).

In addition the regularly exercised muscle show more synchronous in the firing of motor unit (Baylor and Spirduso 1988). Milner-Brown, Stein and Lee (1975) hypothesized that synchronization of motor units might arise from regular use of muscles to exert large, brief force.

Spirduso (1988) described the central effects of exercise by the finding that make shorter in premotor time (PMT) in old active subjects than old inactive group.

This may be due to :

a) the effect of exercise on the oxidative capacity of the brain

b) the trophic effect that exercise may have on central nervous system function (Baylor and Spirduso 1988).

The reaction time of the weightlifter national team (W1) was shorter than weightlifter university team (W2) while the reaction time of gymnastic national team (G1) was longer than gymnastic university team (G2). This may be due to difference in training period between the national team and the university team. The national team trained longer than university team (the training time of W1=13-15 yrs, W2=6 mth-3yrs, G1=6-15 yrs, G2=2mth-3 yrs). Hakkinen,et al (1985) also showed that magnitude of neural change may be due to the duration of training. Harbin, et al 1989 also found the significant different between professional and amateur response times which fifty percent of 180 amateur athletes had a response time >2 SD slower than professional athletes. The opposite finding between the reaction time of W1, W2 and G1, G2 may be due to different training. Weightlifter trained for improve power. It was shown that power improvement can shorten the reaction time (Fox 1984). Meanwhile gymnastic trained for balance and flexibility improvement therefore, flexibility of gymnastic was greater than weightlifter.

The total patellar reflex time (TRT) has been fractionated into reflex latency (LAT) and reflex motor time (MT) components by employing electromyographic techniques. Ryushi, et al (1990) found that LAT was negatively correlated with the percentage number of FT fibers and FT :ST ratio in the vastus lateralis muscle whereas the motor time, the total patellar reflex (MT and TRT) were not significantly correlated with the muscle fiber types.The present results, show that the weightlifter didn't show shorter in the total reflex time when compare with other type of sports and the control group (Table 3.8).The most of W1 had experience of knee pain during training and competition period. These may cause significantly longer TRT of the left leg but not significantly longer TRT of the right leg in W1 group.

Movement time of both legs of table tennis national team were significantly less than control and weightlifter national team. The movement time of the left hand was significantly lesser than control but not significantly different in the right hand. In table tennis game must have contact the ball at a specific point in space and specific time. Then, table tennis player must be trained to make decision and moving the body as fast as possible to intercept the ball properly within a very short delay. Furthermore, the player is usually trained to strike the ball at an optimal speed. Proteau, et al (1989) evaluated the quality of motor response for different level of expectancy and time constant in a two-choice coincident -anticipation task. He found that when the stimulus traveled at a high speed and trade off took place, the choice reaction time decreased as the probability of the event increased. It means that at the high speed of the stimulus travelling, the choice reaction time showed decrease as the error showed increase. In 1989, Schneider, et al conducted dynamical analyses of a human multisegment during the practice. They found that practice subjects achieved significantly shorter the movement time. As movement time decrease, all joint-moment components (except gravity) increased and the moment-time and EMG profile were changed significantly. The timing and organization of muscle recruitment patterns were changed considerably, subjects used muscle moments to counterbalance motion-dependent moments and consequently produced a faster movement. They summarized that practice is necessary for the subjects to coordinate the active and passive intersegmental dynamics of the moving arm which passive force were inertial, centripetal force as well as those from various connective tissue.

When compare the movement time of the national team and the university team were compared, it was found that the movement time of both the leg and the hand of the weightlifter national team were longer than the university team in all direction of movement. The weightlifters in the national team (W1) had evidence of leg injury during training which may lead to a slower of the movement time when compared to the weightlifter university team. However, Harbin (1989) found no significant relationship between slow response time and injury. He found that during injury the response time was slower and faster after rehabilitation of athletic injuries. The movement time of table tennis national team was shorter than the university team of both the hand and the leg. It may be due to the different duration of training.

Figure 17,19,21,23 showed that the movement time of the abduction of both hand and leg (270° for Rt leg, 90° for Lt leg, 270° for Rt hand, 90° for Lt hand) were lesser than the movement time of the adduction of both hand and leg (90° for Rt leg, 270° for Lt leg, 90° for Rt hand, 270° for Lt hand). This was found in almost all of sports types except gymnastic national team. The present findings are the same as Pralance (1974) and Fisk et al (1985), who founded that adductive movement took longer movement time and also longer preparatory reaction times. Schneirla (1959) and Tarantino (1970) suggested that the two types of movement around the shoulder joint are controlled by different behavior-regulating mechanisms. Thus, movement time for abduction and adduction was not equal. Leisman (1990) proposed that abductive movements are controlled by the contralateral brain hemisphere while adductive movement are controlled by either hemisphere. He hypothesized that abductive movement are related to the lateral system which consisting of ipsilateral cortical projections to the cells of origin of a lateral brainstem pathway, which in turn projects to the contralateral side of the spinal cord. The control of adductive movement is related to the medial system which projects billaterally to the spinal cord. From the study about the abductive or adductive movement of prefered and non prefered hand of Bradshaw (1988, 1990) showed that movement time of prefered hand was faster than non-prefered hand and abductive responses (movement time) were faster than adductive, especially with the prefered right hand. The stronger with the right hand of abductive superiorities may be due to the selective deployment of attention towards right hemispace during normal operations with the prefered right hand.

The flicker fusion frequency in the weightlifter national team showed significantly higher than gymnastic, basketball and table tennis national team (Table 3.9). The flicker fusion frequency rate is an indicator for estimating the visual fatigue stage (Marata 1991). Then it can proposed that the visual fatigue of gymnastic, basket ball and table tennis were faster than weightlifter. Furthermore, Fig. 7 showed negative correlation between flicker fusion frequency rate and the movement time of the right hand at 0° direction. This means that subject who has higher flicker fusion frequency rate should has the shorter movement time. In 1989, Zuurmond also found the moderate correlation between critical flicker fusion frequency and the initiation time of the choice reaction time double task but the present result didn't show the correlation between flicker fusion frequency and simple reaction time. So, it may indicate that flicker fusion frequency seem to have a relatively complex neuronal circuits in the brain those may partly common to neuronal circuits those use in movement speed control and choice reaction.

Gauthier (1988) studied about the coordination of eye and hand movements in response to motion of a visual target. They hypothesized that the control of coordination results from reciprocal exchanges of information between two, or more sensorimotor system involved in the execution of a common, or conjugated tasks. This control is elaborated from sensory and motor information derived from the subsystems involved in the coordinated action. The control of coordination acts as a complement to the normal control in each subsystem. They assume that the control of coordination as defined above is the result of the activation of a specialized central nervous structure which is inactive when a subsystem is operating along or independent of other subsystem Fig. 25 illustrates description of the control of coordination. At birth, the wiring between the two processing units is functionally very tight. Maturation and motor learning allows a mediation of the interaction between the two systems.

From the data (Fig. 8) MT of the right hand were significantly correlated with MT of the right leg at 0°

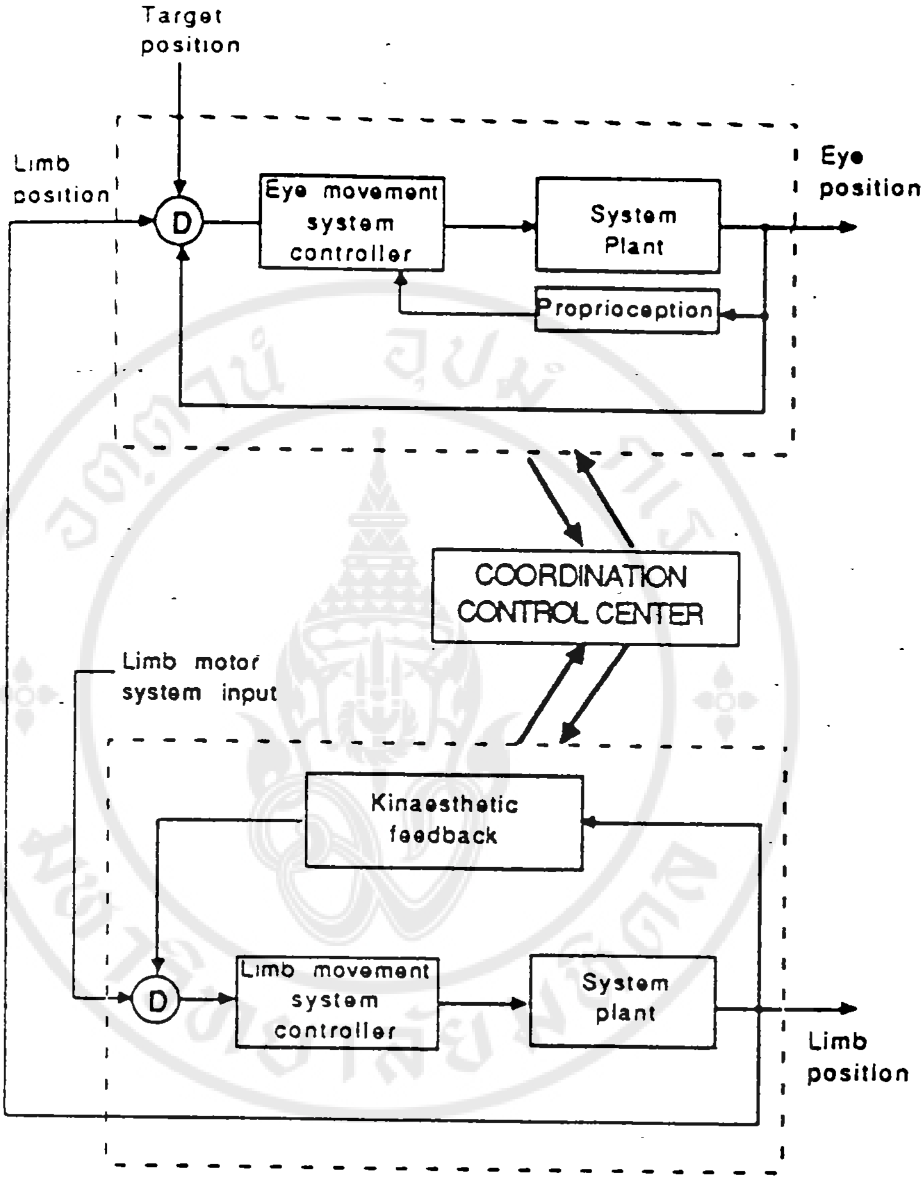

Fig. 25 Descriptive model of oculo-manual coordination control. Coordination control results from reciprocal exchange of information between two systems (eye motor system and arm motor system) involved in the execution of a common task. This control superimposes its action on the control proper to each system. The sites of action of the signals generated by the coordination controller are hypothetical. The schema illustrates the tracking condition in which the hand is used as visual target. The model assumes that coordination control is mediated by a specialized structure (coordination controller) receiving information from both systems. These information may be a combination of afferent and efferent signals issued from the sensorimotor systems involved in the task. The model is represented in the eye tracking of the hand situation where the limb constitutes the visual input activating the eye movement system

and 180° direction. The correlation between Rt and Lt hand and Rt and Lt leg at 0° direction were also significant. This indicates that the athletes had faster motor control. The reflex time of the right leg was also significantly correlated with the reaction time of the right bigtoe when stimulated at the right heel. This may indicate that the control by higher motor center (brain) may link closely with the control by lower motor center (spinal).

The present data also shows that the reactions to visual system, auditory system and pressure receptor system were positively correlated with each other. Therefore, the athletes who was faster in response to one type of sensory stimulation should be faster in response to other types of the sensory stimulation also.

The verbal and non-verbal counting are automatic speech (Kotsopoulos and Mellor 1986). The verbal counting uses longer neuronal circuit than does the non-verbal counting. The later involves the reacting neural circuits in the brain and muscles. The initiation of a sequential speech demands premovement motor readiness for voiceless consonant and the preparatory motor adjustments to voicing. The non-verbal counting uses shorter neuronal circuit, it only involves the reacting of neural circuits within the brain. The result shows that both verbal and non-verbal counting of weightlifter national team (W1) were fastest when compare with other athletes. In 1985, Hoffmann and his co-worker found that speech pause time during a counting test correlated with the simple reaction time of both depressed patients and controls. This means that the person who react faster should be faster in the counting speed. However, simple reaction time and the counting speed of both verbal and non-verbal didn't show significant relation between them in the present study.

CHAPTER VII

SUMMARY

The different programs of physical training seem to have different effects on physical performances in various athletes. The strength training can improve strength so much but very little in aerobic capacity. Meanwhile aerobic capacity was improved very much in the group of basketball and table tennis. Finally, balance and flexibility were much improved in the gymnastic group.

Not only physical performances change with the training but the psychomotor speed also shows change with the training. The changing of psychomotor speeds seem to occure both in the central and peripheral neuronal circuits. Most of it seems to occure in the central nervous system because it shows some evident in the present results. From the result, the visual reaction time of weightlifter national team was shortest when compare with the other types of sport and with the control group. The verbal and non-verbal counting of the weightlifter were fastest and the FFF was greatest. The strength training not only can improve speed of reacting but the practice also improve the coordination of the extremities. In addition, the stretching exercise of the gymnastic group could lengthen the reaction time. The present result didn't clearly show that the reaction time could be shorten with the improvement of the aerobic capacity. But it showed that there are close relationships between different psychomotor speeds, which indicates that the training which can shorten one type of the reaction can also shorten other types of the reaction which may have long or short loop neuronal citcuits.

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APPENDIX

The correlation equation between different psychomotor speed

X = Flicker Fusion Frequency

Y = movement time RT hand	A	B	r	n
W1	39.65	-0.016	-0.24	10
W2	41.03	-0.036	-0.62	7
W1+2	40	-0.02	-0.36	17
G1	35.35	-0.03	-0.37	7
G2	37.23	-0.0017	-0.06	10
G1+2	37.54	-0.02	-0.25	17
C	41.41	-0.032	-0.73**	10
B1	32.63	0.0035	0.049	9
T1	34.78	-0.0099	-0.17	8
T2	41.02	-0.037	-0.65*	8
T1+2	38.40	-0.03	-0.45*	16
Mix	38.71	-0.024	-0.38***	69

X = MT Rt hand at 0

Y = MT Rt leg at 0

W1	147.22	0.57	0.68*	8
W2	137.52	-0.18	-0.18	7
W1+2	99.92	0.56	0.42	15
G1	156.73	0.39	0.22	7
G2	-23.58	1.43	0.84***	10
G1+2	100.68	0.73	0.52*	17
C	180.78	0.18	0.24	10
B1	23.12	0.93	0.51	9
T1	49.597	0.63	0.53	7
T2	196.73	0.29	0.55	8
T1+2	137.07	0.395	0.37	15
Mix	97.10	0.62	0.47***	66

X = MT Rt leg at 0

Y = Reflex time Right leg

W1	190.96	-0.20	-0.41	3
W2	111.28	0.07	0.61	7
W1+2	106.57	0.16	0.61*	10
G1	-47.77	0.73	0.61	5
G2	123.99	0.08	0.28	10
G1+2	131.27	0.02	0.06	15
C	95.80	0.15	0.24	10
B1	142.90	0.13	0.36	7
T1	44.19	0.59	0.81*	7
T2	109.28	0.195	0.24	7
T1+2	65.39	0.41	0.65**	14
Mix	109.42	0.17	0.38**	56

X = MT Rt leg at 0
Y = MT Lt leg at 0

	A	B	r	n
W1	83.69	0.68	0.73*	8
W2	73.32	0.67	0.78*	7
W1+2	68.51	0.732	0.89***	15
G1	81.04	0.72	0.82*	7
G2	25.52	0.89	0.97***	10
G1+2	40.93	0.851	0.925***	17
C	119.90	0.50	0.41	10
B1	53.83	0.64	0.68*	9
T1	-28.599	1.22	0.93***	7
T2	-75.79	1.46	0.94***	8
T1+2	-39.17	1.299	0.95***	15
Mix	58.46	0.79	0.83***	66

X = MT Rt hand at 0
Y = MT Lt hand at 0

W1	95.45	0.44	0.77**	10
W2	83.09	0.22	0.31	7
W1+2	77.76	0.45	0.59**	17
G1	73.99	0.54	0.80*	7
G2	24.87	0.88	0.82***	10
G1+2	37.37	0.78	0.80***	17
C	40.34	0.98	0.68*	10
B1	19.99	0.99	0.81**	9
T1	5.65	0.98	0.78*	8
T2	68.60	0.71	0.78*	8
T1+2	42.02	0.81	0.76***	16
Mix	50.77	0.72	0.72***	69

X = Reflex time Rt leg
Y = RT of RBT when tactile at Rt heel

W1	144.79	0.27	0.32	3
W1	241.09	-0.21	-0.05	7
W1+2	291.15	-0.65	-0.36	10
G1	189.35	0.43	0.60	6
G2	131.78	0.62	0.52	10
G1+2	136.12	0.66	0.58**	16
C	155.399	0.42	0.47	10
B1	161.87	0.34	0.30	8
T1	167.09	0.52	0.69*	8
T2	133.92	0.46	0.89**	7
T1+2	159.17	0.44	0.57*	15
Mix	183.17	0.26	0.33**	59

X = Visual RT of RI
Y = Auditory RT of RI

	A	B	r	n
W1	192.21	0.16	0.22	10
W2	113.87	0.42	0.40	7
W1+2	159.25	0.31	0.38	17
G1	146.18	0.44	0.39	7
G2	49.84	0.69	0.75**	10
G1+2	71.33	0.66	0.65**	17
C	-10.58	0.98	0.91***	10
B1	247.98	0.03	0.03	9
T1	76.44	0.69	0.32	8
T2	-47.22	1.17	0.87**	8
T1+2	-11.986	1.03	0.64**	16
Mix	222.40	0.07	0.10	69

X = Visual RT of RI
Y = Tactile RT of RI

W1	127.66	0.097	0.23	10
W2	-23.26	0.70	0.90**	7
W1+2	81.65	0.301	0.59**	17
G1	74.51	0.41	0.40	7
G2	70.20	0.37	0.63*	10
G1+2	74.77	0.368	0.57**	17
C	60.54	0.42	0.598*	10
B1	191.27	-0.13	-0.17	9
T1	99.48	0.25	0.27	8
T2	129.55	0.19	0.25	8
T1+2	142.45	0.107	0.13	16
Mix	93.33	0.29	0.43***	69

X = Auditory RT of RI
Y = Tactile RT of RI

W1	69.98	0.35	0.60*	10
W2	105.19	0.23	0.36	7
W1+2	82.01	0.307	0.492*	17
G1	-30.38	0.795	0.91***	7
G2	107.25	0.24	0.39	10
G1+2	89.36	0.325	0.511*	17
C	59.19	0.45	0.698*	10
B1	63.12	0.39	0.47	9
T1	146.57	0.07	0.15	8
T2	99.096	0.33	0.59	8
T1+2	138.05	0.31	0.25	16
Mix	122.32	0.17	0.35***	69

X = Tactile RT (acromium)
Y = RT of RI when Tactile at 4th finger (Rt)

	A	B	r	n
W1	94.65	0.44	0.26	10
W2	33.03	1.00	0.53	7
W1+2	19.22	1.00	0.52*	17
G1	25.397	0.87	0.94***	7
G2	35.97	0.89	0.59*	10
G1+2	38.97	0.84	0.62**	17
C	54.77	0.71	0.72**	10
B1	136.28	0.18	0.26	9
T1	91.31	0.48	0.66*	8
T2	127.11	0.29	0.24	8
T1+2	105.45	0.40	0.412	16
Mix	111.17	0.387	0.397***	69

X = non-verbal counting
Y = verbal counting

	A	B	r	n
W1	0.19	0.97	0.83***	10
W2	28.74	0.799	0.83**	7
W1+2	86.21	0.30	0.46	17
G1	46.20	0.58	0.90**	7
G2	40.75	0.72	0.82***	10
G1+2	54.64	0.58	0.73***	17
C	26.58	0.798	0.80**	10
B1	51.41	0.57	0.46	9
T1	-27.58	1.25	0.985***	8
T2	50.44	0.74	0.74*	8
T1+2	45.70	0.74	0.82***	16
Mix	38.33	0.71	0.75***	68

X = verbal counting
Y = flicker fusion frequency

	A	B	r	n
W1	51.42	-0.13	-0.56*	10
W2	47.52	-0.08	-0.62	7
W1+2	47.38	-0.09	-0.56**	17
G1	49.28	-0.16	-0.51	7
G2	42.96	-0.04	-0.39	10
G1+2	34.41	-0.006	-0.02	17
C	43.72	-0.07	-0.38	10
B1	26.81	0.05	0.17	9
T1	33.46	-0.001	-0.009	8
T2	23.60	0.09	0.40	8
T1+2	31.26	0.02	0.12	16
Mix	38.48	-0.03	-0.21*	68

X = MT Rt hand at 180°
Y = MT Rt leg at 180°

	A	B	r	n
W1	64.95	1.31	0.74*	8
W2	107.72	1.24	0.68	6
W1+2	124.07	0.96	0.79***	14
G1	306.37	-0.47	-0.17	6
G2	171.19	0.29	0.23	9
G1+2	235.68	0.04	0.03	15
C	234.59	-0.08	-0.06	10
B1	67.95	0.75	0.53	9
T1	65.15	0.89	0.79**	8
T2	267.83	-0.30	-0.25	8
T1+2	115.13	0.67	0.53*	16
Mix	150.22	0.47	0.38***	64

X = VO_2
Y = FFF

	A	B	r	n
W1	43.34	-0.13	-0.3	10
W2	35.79	0.01	0.03	7
W1+2	41.2	-0.09	-0.19	17
G1	19.24	0.16	0.15	7
G2	44.86	-0.16	-0.46	10
G1+2	58.14	-0.46	-0.67***	17
C	18.27	0.36	0.80**	10
B1	22.39	0.18	0.45	9
T1	36.93	-0.04	-0.10	8
T2	55.63	-0.46	-0.67*	8
T1+2	41.13	-0.12	-0.37	16
Mix	39.33	-0.09	-0.24*	67

X = MT Rt hand at 0°

Y = RAG (Right arm girth)

	A	B	r	n
W1	32.32	0.01	0.6	6
W2	26.63	-0.01	-0.698	3
W1+2	30.68	-0.005	0.06	9
G1	25.15	0.02	0.35	6
G2	27.14	-0.002	-0.07	10
G1+2	26.62	-0.004	0.11	16
C	26.9	-0.003	-0.10	10
B1	27.82	-0.002	-0.05	9
T1	27.74	-0.01	-0.57	8
T2	24.00	0.009	0.58	8
T1+2	25.50	-0.001	0.07	16
Mix	27.21	0.0006	0.01	60

X = MT

Y = HG (relative hand grip strength)

	A	B	r	n
W1	69.7	-0.06	-0.29	10
W2	75.94	-0.02	-0.11	6
W1+2	75.1	-0.06	-0.31	16
G1	83.72	-0.01	-0.05	7
G2	80.40	-0.008	-0.07	10
G1+2	80.90	-0.004	-0.03	17
C	54.70	0.11	0.62*	10
B1	65.20	-0.003	0.03	9
T1	87.30	-0.08	-0.65	6
T2	63.30	0.05	0.497	8
T1+2	71.75	-0.008	-0.07	14

Table Appendix The movement time of the right, left of hand and feet at different direction.

	C	W1	W2	G1	G2	B1	T1	T2
MT Rt leg at 0°	214.51±14.53	247.76±17.9 W1B1* W1T1** W1W2***	115.00±25.29 ** W2T2*** W2G2*	230.86±32.00 G1T1*	213.79±35.21	174.41±25.73	150.09±28.5 * T1T2**	241.53±15.41
MT Rt leg at 90°	265.90±22.06	325.01±25.8 * W1B1* W1T1*** W1W2***	169.96±27.97 ** W2T2**	245.07±42.50	254.83±38.37	251.94±28.7	168.7±25.4 ** T1T2**	290.53±33.53
MT Rt leg at 180°	219.72±23.80	263.65±26.0 W1B1* W1T1* W1W2*	159.77±31.50 W2T2*	244.23±35.96 G1T1**	207.49±25.7	177.44±24.13	154.9±32.3 T1T2*	228.84±21.17
MT Rt leg at 270°	184.85±18.41	224.46±14.6 W1B1** W1W2*	147.89±32.74	234.49±31.60 G1B1*	169.29±29.67	134.73±25.4	154.1±40.7	209.51±17.17
MT Lt leg at 0°	228.17±17.69	252.55±16.75 W1B1** W1T1** W1W2***	149.80±21.62 ** W2T2***	246.34±27.96 G1B1* G1T1*	216.52±32.55	166.01±24.47 *	138.6±37.8 * T1T2**	275.96±23.96
MT Lt leg at 90°	207.15±13.80	226.45±10.81 W1B1* W1W2**	135.60±27.61 * W2T2*	256.71±41.10 G1T1*	170.81±32.78	170.43±26.45	148.2±43.7	210.23±15.37
MT Lt leg at 180°	258.66±14.37	230.78±13.18 W1B1* W1T1** W1W2*	172.89±23.73 **	245.49±36.20 G1B1* G1T1*	223.41±28.27	171.73±22.99	144.5±29.1	229.03±25.45
MT Lt leg at 270°	282.53±12.82	326.31±18.7 * W1B1*** W1T1*** W1W2***	194.49±25.31 ** W2T2*	255.46±38.20	260.52±35.98	195.18±29.16 **	171.5±33.2 ** T1T2**	287.14±24.20

	C	W1	W2	G1	G2	B1	T1	T2
MT Rt arm at 0°	188.71±19.34	165.63±19.1	127.60±25.23*	185.97±17.30	156.69±20.55	162.6±14.07	154.1±23.0	154.13±29.08
MT Rt arm at 90°	188.74±18.54	140.40±14.4* W1W2*	100.59±17.61***	149.56±23.10	159.27±16.02	169.38±16.61	142.9±29.2	124.65±16.54*
MT Rt arm at 180°	176.38±17.31	147.02±12.0	80.94±23.30**	167.09±16.50	136.24±18.98	145.31±16.88	100.3±28.4*	128.26±17.28*
MT Rt arm at 270°	155.68±14.30	125.05±13.4 W1G1*	87.37±20.97**	169.54±21.70 G1G2*	119.76±14.6	122.71±23.7	124.1±21.48	132.54±29.26
MT Lt arm at 0°	198.09±23.64	168.17±10.9 W1W2**	110.89±17.57** W2G2* W2T2*	174.36±11.68	171.07±21.98	181.3±17.27	156.5±29	178.54±26.61
MT Lt arm at 90°	177.63±17.41	119.44± 9.6** W1G1* W1B1*	92.20±18.42** W2G2* W2T2*	160.40±20.00	133.88±14.97*	157.32±18.13	112.2±26.25*	146.53±21.83
MT Lt arm at 180°	167.04±25.30	136.60±11.6	113.97±36.23	163.67±17.70 G1T1* G1G2*	112.67±18.94	149.24±19.72	99.0±26.3*	143.4±29.19
MT Lt arm at 270°	191.76±20.66	149.49±10.6*	130.36±35.14	159.81±10.80	146.7±22.22	160.00±23.02	116.98±16.4**	150.94±21.54