RELIABILITY AND VALIDITY TESTING OF ARCHERY CHRONOMETER AND ANALYSIS OF FOREARM MUSCLES IN THE DRAWING HAND BY USE OF EMG AMONG TURKISH ARCHERS

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ABSTRACT

RELIABILITY AND VALIDITY TESTING OF ARCHERY CHRONOMETER AND ANALYSIS OF FOREARM MUSCLES IN THE DRAWING HAND BY USE OF EMG IN TURKISH ARCHERS

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There is much speculation about the muscular activation patterns upon clicker sound, specifically on whether the release is affected by relaxation of flexors or by the activation of extensors. The purpose of this study (1) To analyze the muscular activities in the forearm of bow hand before and after the clicker' snap by means of EMG synchronized with clicker in Turkey, (2) to test validity and reliability of Clicker Reaction Time Measurer (ClickRTM) by means of EMG synchronized with clicker pulse in Turkish archers.

Ten elite archers, ten beginners, and ten non-archers participated in this study. EMG activity of flexor digitorum superficialis and extensor digitorum muscles were recorded at a sampling frequency of 500 Hz, together with a pulse synchronized with the clicker snap, for twelve shots by each subject. The raw EMG records, one- second before and after the clicker pulse, were rectified and integrated. The data was then averaged at each time station with 100 ms intervals, for successive shots of each subject and later for each group.

The elite archer 's bow release strategy appears to involve simultaneous relaxation of flexors and contraction of extensors, at around 200 ms after the clicker sound. The beginners also employed the same simultaneous contraction and relaxation pattern, however they seem to undergo a preparation phase involving extensor activity before the clicker signal, therefore the co-contraction pattern of both muscle groups showed rather unstable behavior. The non-archers also displayed unstable co-contraction pattern before the stimulus. The above observations contradict the findings of an earlier investigation carried out on elite American archers, which suggested that the finger extension is not the result of forceful muscle contraction, but the bow release is caused by the relaxation of the flexors. However, another investigation of the same nature reported a more active involvement of finger extensors of elite archers, in agreement with our finding.

Key Words: Archery, Electromyography (EMG), Reaction Time, and Clicker Reaction Time.

ÖZ

TÜRK OKÇULARINDA OKÇULUK KRONOMETRESİNİN GÜVENİRLİK VE GEÇERLİĞİNİN TEST EDİLMESİ VE ÖN KOL KASLARINDAKİ AKTİVİTENİN EMG ARACILIĞIYLA ANALİZ EDİLMESİ

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Klikır sesine bağlı olarak ortaya konulan kassal aktiviteyle ilgili özellikle bırakış hareketinin flexor kasların gevşetilmesiyle mi yoksa extensor kasların aktivasyonuylamı gerçekleştirildiği konusunda bir çok farklı görüş mevcuttur. Bunun yanısıra, Klikırın düşüşüne verilen tepkinin süresi, okun uçuş hızı, ok atıldığı sırada hava koşulları da merak konusu olmuştur. Bahsi edilen kritelri ölçmek amacıylada Ertan ve ark. (1996) tarafından Okçuluk Kronometresi adı verilen bir cihaz geliştirilmiştir. Bu çalışmada; (1) bir ok atışı sırasında ön kol kaslarının koordinasyonu ile ilgili yaklaşımlar deneysel olarak değerlendirilmesi, (2) Klikır Reaksiyon Zamanı ölçerinin güvenirlik ve geçerliğinin test edilmesi.

Bu çalışmaya, 10 üst düzey, 10 yeni başlayan okçu ve daha önce hiç ok atmamış 10 denek katılmıştır. Her deneğin 12 atışında klikır'ın düşüşüyle eşzamanlı hale getirilerek flexor digitorum superficialis ve extensor digitorum kaslarının Elektromiyografik (EMG) aktiviteleri 500 Hz frekansla ölçülmüştür. 5 saniye süreyle ölçülmüş olan EMG aktiviteleri, bir saniye klikır öncesi ve bir saniye klikır sonrası olmak üzere toplam iki saniyeye indirgenmiştir.

Üst düzey okçularda flexor kasların gevşetilmesi ve extensor kasların kasılması eşzamanlı olarak klikır sesinden 200 ms sonra oluşan tepkileri içermektedir. Bunun yanısıra, klikır sinyalinden önce her iki kas grubunda stabil kasılma özelliği gözlenmiştir. Yeni başlayan okçularda aynı şekilde her iki kas grubunda kasılma-gevşeme uyumu sergilenmiştir. Okçu olmayan denekler de uyaran öncesinde düzensiz bir yapı sergilemişlerdir. Okçu olmayanları diğerlerinden ayıran en önemli özellik ise, bu grubun flexor kasların gevşetilmesiyle bırakışı gerçekleştirmeleridir. Ortya konulan bu bulgular daha önce Amerikalı elit okçularla yapılan ve parmak extensiyonunun extensor kaslardaki aktif kasılmaya bağlı olarak değil, flexor kasların gevşetilmesiyle oluştuğunu ileri süren çalışmayla çelişmektedir. Bununla birlikte, bu araştırmada ortaya konulan bulgular benzer şekilde yapılan ve parmak extensiyonunun extensor kasların aktif katılımıyla oluştuğunu ileri süren çalışmayla benzerlik göstermektedir.

EMG ölçümünden elde edilen gerçek reaksiyon zamanı değerleri ile geliştirilmiş cihazdan elde edilen reaksiyon zamanları arasında anlamlı ilişki bulunmuştur ($r = .787$, $p < 0.01$). Ayarıca bir hafta arayla alınan ölçümler arasında yüksek anlamlı ilişki gözlenmiştir ($p < 0.01$).

Anahtar Kelimeler: Okçuluk, Elektromiyografi (EMG), Reaksiyon Zamanı, Klikır Reaksiyon Zamanı.

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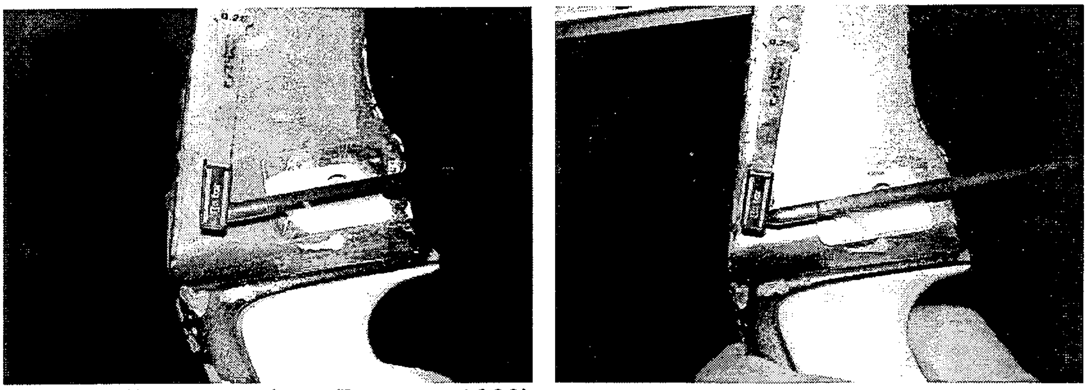
CHAPTER 1

1. INTRODUCTION

Athletic performance prediction includes determining base line levels (anthropometric, physiological, genetic, psychological, and performance measurements) and making predictions based on baseline data using multiple regression techniques. The kinds of variables included in the analysis depend on the characteristics of the sport being examined. For instance, in determining predictive factors associated with running, aerobic capacity would form an important part of baseline information. However, in the study of less active, self-paced sports such as archery, this information may be less important (Landers, Boutcher & Wang, 1986). In understanding basic requirments of archery for reaching high performance level, one should first describe the characteristics of archery, then try to determine base line levels of this sport by gathering data.

Archery can be described as a static sport requiring strenght and endurence of the upper body, in particular the shoulder girdle (Mann, 1984; Mann & Littke, 1989). Skill in archery is defined as the ability to shoot an arrow at a given target with accuracy (Leroyer, 1992). Some of the researchers (Leroyer, 1992) describe the shot as a three phase movement: the stance, the arming and the sighting. On the other hand, Nishizono (1996) divides the stages of a shot into six: Bow Hold, Drawing, Full Draw, Aiming, Release and Follow-through. All these phases are the stable sequences of the movements and are suitable for studying the motor control and skill-acquiring processes of the voluntary movement.

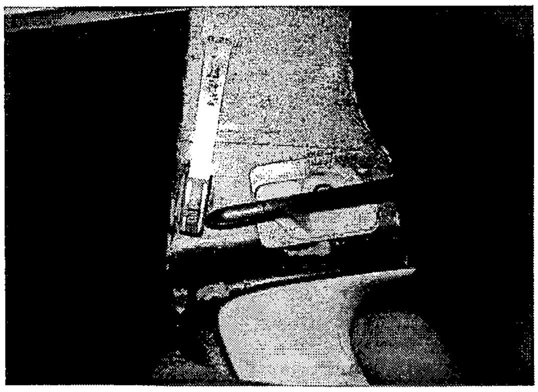
The archer pushes the bow and pulls the bowstring from the beginnig of the arming phase, until the release (Picture 1.1. a & b) (Leroyer, 1992). Release phase must be well-balanced and highly reproducable to get a good record in an archery competition (Nishizono, 1996). When archer reaches his or her final position a device called clicker falls, producing a light sound which is the stimulus for the archer to extend his or her pull fingers, which induces the release of the bowstring (Picture 1.2.). The clicker is known to improve an archer's score and is used by all target archers (Leroyer, 1992).



a. b.

Picture 1. 1.: (a) archer pushes the bow and pulls the bowstring to reach final position. (b) archer reaches his or her final position.

The clicker consists of a flat spring with one end fixed at the window of the bow and the other resting on the arrow (Pictures 1.1. & 1.2.). As the point of the arrow is drawn past the clicker, it snaps or clicks against the bow and the archer releases the arrow (Picture 1.2.). The clicker ensures the arrow is drawn back



Picture 1. 2.: Clicker snapped after reaching final position producing a light sound.

exactly the same distance each time. The contrary effect of the clicker is that the archer must coordinate several factors for optimal accuracy. These include aiming, maintining a rigid stance, holding a 20 – 23 kg draw weight bow at full draw, and gradually drawing the arrow past the clicker before releasing. This process typically takes 3 – 6 s per shot (Mann, 1984; Leroyer, 1992).

When the clicker snaps, archer should response to this stimuli as soon as possible. By doing this, he or she stabilize the drawing length of the bow. Archer must coordinate the muscule activaty of the whole body to reach optimal accuracy. Especially, there should be a perfect muscule activaty pattern in the forearm and pull fingers.

There is considerable speculation among coaches and athletes about the muscular activation patterns that achieve the smootest possible release of the bowstring and consequently, lead to higher performances. There are two different approaches of the muscular activation in the forearm and pull fingers: First group of the researchers suggest that, an archer should release the bowstring through a relaxation of the muscles that maintained the flexed position of the fingers around the string. That is, rather than attemtpting to affect the release by actively extending the fingers via concentric muscle action it is suggested that the archer should simply relax the flexor musculature as the force of the string on the fingers is sufficient to produce their extension. Supporting rationale indicates that this relaxation process will result in a smoother release of the bowstring, as it is suggested that an active extension of the fingers is more likely to produce lateral deflections of the bow string and less consistent shot-to-shot performance (Martin, 1990; McKinney, 1997).

Other group of researchers believe that when the click signal comes, the archer relaxes the flexor group muscles of the forearm and actively contracts the extensor group muscle to produce the release. In this type of muscle activation pattern the archer should produce a harmony between agonist and antagonist muscles. This muscular coordination pattern needs more time to learn and train.

To constitute a baseline from the different aspects for archery performance prediction Ertan et al. (1996) developed a specially designed device called archery chronometer measuring (1) the reaction time of an archer to the clicker' snap and (2) flying time (FT) or average speed (AS) of the arrow in a given distance (3) wind speed and direction (4) temperature. In measuring the reaction time of an archer, chronometer starts counting when the clicker falls from the point of the arrow and stops when the metal point of the arrow passes in front of a sensor (sensible to metal) that is situated 1.5-cm distance away from the clicker. This time gap is named as Clicker Reaction Time (ClickRT). In measuring flying time or average speed of the arrow in a given distance, a second chronometer starts counting when the metal point of arrow passes in front of the sensor and stops when the arrow hits the target by use of a vibration detector attached to the target. Ertan et al. (1996) investigated the relations between the ClickRT, flying time (FT) or average speed (AS) of the arrow in a given distance and scored point in target archery. However it was not tested if this device gives reliable and valid results in field of target archery.

There are two purposes of the current study. The first one is to investigate the reliability and the validity of clicker reaction time measurer (ClickRTM) by using EMG records of the related musculature. The second purpose is to analyze muscular activities in the forearm of the bow hand by means of EMG synchronized with clicker, among Turkish archers.

1.1 Purpose

1. To analyze the muscular activities in the forearm of bow hand before and after the clicker' snap by means of EMG synchronized with clicker in Turkey.
2. To test validity of Clicker Reaction Time Measurer (ClickRTM) by means of EMG synchronized with clicker pulse in Turkish archers.
3. To test the reliability of Archery Chronometer of Ertan et al. (1996) by using test re-test method in Turkish archers.

1.2 Problem

1. What are the characteristics of muscular strategies before and after the clicker' snap in skilled archers, beginner archers, and non-archers in Turkey?
2. Is the Clicker Reaction Time Measurer (ClickRTM) valid in terms of measuring a special response to clicker' snap?
3. Does the Archery Chronometer make reliable measurement?

1.3 Hypothesis

1. The extensor Digitorum Muscle will be involved actively in the release movement after the click signal.
2. There is no relationship between Real Reaction Times from EMG and Clicker Reaction Times (ClickRT).
3. There is no relationship between test re-test scores gathered by Archery Chronometer.

1.3 Limitations

1. This study is limited with the Turkish National Archery Teams (male and female) for skilled (elite) archers, with Ankara Archery club for beginner archers, and with university students and stuff for non-archers.
2. Shots are made in laboratory conditions from 5-m distance with 12 arrows.
3. This study is limited with forearm muscle analysis and the validity and reliability testing of Clicker Reaction Time Measurer.

1.4 Significance of the Study

The first aim of this study is to test the reliability and validity of ClickRTM. To reach this aim an EMG measurement is made in laboratory conditions. It is, of course, possible to examine the archer's reaction times to the clicker's snap by using EMG synchronized with clicker. The advantage of CRTM is that it is moveable and it can be used in the real archery conditions. After this investigation researcher will be able to see whether this device can be safely used or not. If the results show that it can be used safely it will be easier and useful for archers to measure their reactions and correlate them with their points in target archery.

As mentioned above, there is a dilemma; does release of bowstring occur by relaxation of flexor muscles in the fore arm or active contraction of extensor group muscles of bow hand? How does the muscle strategy differ among non-archers, beginners and skilled archers? Is there any learning effect to the special response to the clicker's snap? By answering these questions, researcher will be able to give some advises to archery trainers and archers.

1.5 Definitions of the terms

Aim: The placement of a sight pin on the center of the target; if a sight is not used, placement of the tip of the arrow on a specific point while shooting at a target over a given distance.

Bow Arm: The hand that the archer prefers to use for holding the bow during shooting.

Clicker: A small metal device mounted on the sight window in front of the arrow rest that indicates full draw has been attained by snapping off of the arrow point with an audible click.

End: A set number of arrows shot before going to the target to score and retrieve them; the number may be three, five, or six in target archery.

FITA: Fédération Internationale de Tir à L'Arc- The organization responsible for conducting world championship contests in archery.

Release: The act of putting the arrow into flight due to a release of pressure on the bowstring by either the fingers (target archery) or a release device (bow hunting).

String Fingers: The fingers used to hold the nocked arrow in place on the bowstring during the draw.

CHAPTER 2

2. LITERATURE REVEIW

2.1. ELECTROMYOGRAPHY

Electromyography may be defined as the recording and study of the intrinsic electrical properties of skeletal muscles. To obtain its present status required many years of progress in instrumentation, laboratory and clinical trials (Rodriguez and Oester, 1967). Because the EMG represents the measurement of sarcolemmal action potentials, it provides a window into the nervous system (Denny-Brown, 1949; Ducheme & Goubel, 1993; Hof, 1984; Loeb & Gans, 1 986; Perry & Bekey, 1981; Person, 1963; Sited in Enoka, 1994). The EMG signal offers a potential gold mine of information to both the clinician and the researcher. EMG can be used to detect gait difficulties, treat incontinence, and implement effective biofeedback therapy. Surface EMG is also widely used in an effort to understand a number of research issues including the manner in which groups of muscles are coactivated around a joint, the relationship between muscular force and muscle electrical activity, and neuromuscular adaptations accompanying motor learning and exercise. However, EMG is a tool not without its hidden weaknesses, and these problems have the potential to mask any benefit obtained from the recorded information (Kamen & Caldwell, 1996).

In general, there will be no EMG unless it has been commended by motor neurons. The most common approach to measure EMG is to place an electrode (a type of probe that can measure voltage) near an excitable membrane and to record the action potentials as outside individual muscle cells, or outside the

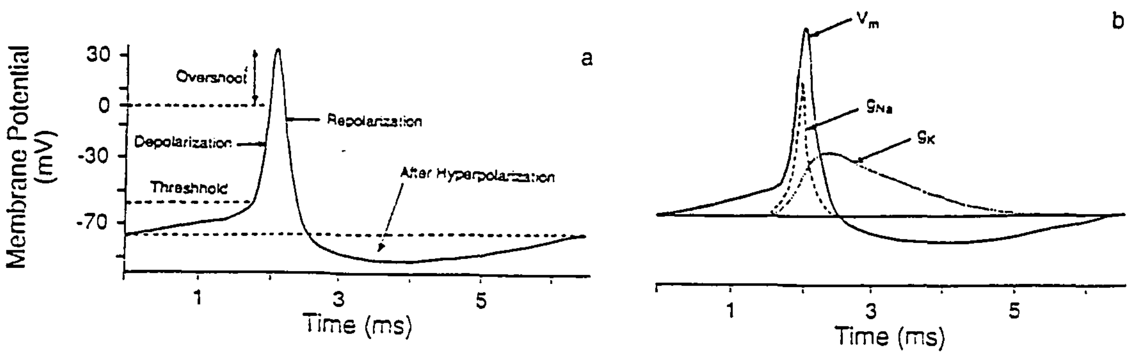


Figure 2.1: A schematic diagram of the action potential indicating (a) its phases and (b) its conductance changes.

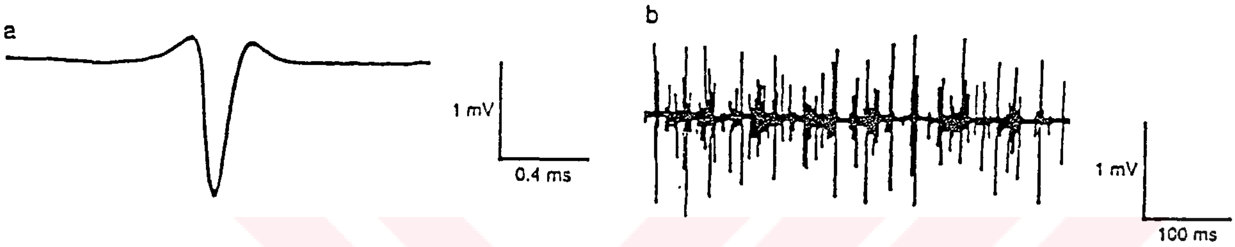


Figure 2.2: EMG records of (a) one and (b) many action potentials. Notice the difference in the time scale for the two records.

muscle. The most common approach is to place the electrode on the skin overlying the muscle; the electrode is outside the muscle. They pass the electrode. With this technique we can record an action potential as a voltage time event. We used this procedure to-measure the action for Figure 2.1.; but in that instance the electrode was placed inside the cell. With EMG, we place the electrode outside the muscle cell and get an extracellular measurement of the change in voltage over time (Figure 2.2.). The electrode, however, can be inside the muscle (intramuscular), although any extracellulary record action potential usually has a triphasic shape (Figure 2.2.a). The reason for this shape is indicated in the diagram in Figure 2.3, which shows the association between the ionic events across the membrane and the recorded potential. An electrode is placed near an excitable membrane, outside the cell, to record the potential in the area (relative to some remote reference) as the action potential approaches, reaches, and passes by the electrode. The electrode is on the right side of the diagram in Figure 2.3; this is the leading edge of the action potential. The central element of the action potential is the region where the polarity across the membrane has been reversed. This is caused by an influx of Na ions and is apparent as the negative potential corresponds to positive ions flowing into the cell. On each side of this negative phase, there is a single positive phase.

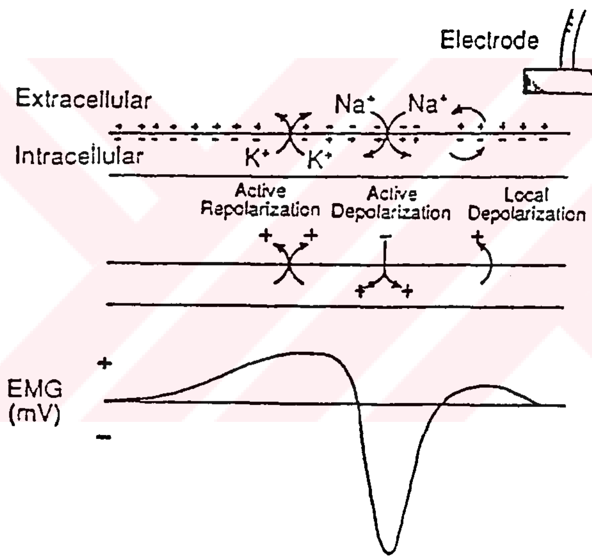


Figure 2.3: Association between the movement of ions across the sarcolemma (upper row), the corresponding current flow (middle row), and the shape of the extracellulary-recorded action potential (bottom row).

The initial positive phase (the right side of the diagram) is due to passive local depolarisation of the membrane (i.e., the membrane is less polarised). This happens because some Na^{-} ions move forward from the region of reversed polarity in the intracellular fluid due to an electrical attraction (positive to negative), and some negatively charged ions in the extracellular fluid move backward (Enoka, 1994).

2.2. EMG ELECTRODES

The electrode serves as antenna and can be arranged in either a monopolar or bipolar mode. With a monopolar mode, one electrode is placed over the signal source (i.g., muscle), and the signal that it senses (due to influx of Na and efflux of K) is compared with that at a distant location (ground). In contrast, a bipolar arrangement has two electrodes over the signal source and the output is the difference between the signals sensed by the two electrodes. Consequently, a monopolar arrangement is necessary to determine the absolute magnitude of the signal, whereas a bipolar configuration allows us to record selectively from a localized signal source (Enoka, 1994).

The type of electrode chosen depends on the nature the information required and the muscle being examined (Kamen & Candwell, 1996; Latash, 1998; Rodriguez, 1967; Taverner, 1967; Basmajian, 1974). Their selection and placement are of considerable importance. Those used in sports biomechanics are usually one of three types; the drawbacks and advantages of which summarised below (Bartlett, 1997; Burdan & Bartlett, 1997).

2.2.1. Passive Surface Electrodes

These are placed on the skin and are up to 1 cm in diameter. They are usually silver-silver chloride and are used with conducting gels, which contain chloride. Passive surface electrodes are convenient, readily available, require little operator training and cause little or no discomfort. However, it is often necessary to reduce the skin to electrode contact resistance, which is relatively time consuming. Electrode gel is used to avoid poor electrical contact and pressure may need to be applied by the use of adhesive strips. However, applying pressure to an electrode when it is in contact with the skin can cause an artifact voltage, which is indistinguishable from the signal. This can be removed in a similar way to cable artifacts.

These electrodes have several limitations. They are not ideal for fine movement, and are mainly used for fairly large groups of muscles or for global pick up. The separation distance between the detection electrodes is important - the closer they are, the more localized the pick up. They are not suitable for deep muscles, and provide an average measure of the activity of superficial muscles. They do not respond solely to the underlying muscle, but also to neighboring ones, including deep muscles. The term cross talk is used to describe the interference of EMG signals from muscles other than the ones under the electrode. For example, surface electrodes used to detect activity from the triceps brachii might pick up signals from the deltoid during the strong abduction at the shoulder. Cross talk is usually only a serious problem at low or zero activation levels and can be minimized by careful choice of electrode location (Bartlett, 1997).

2.2.2. Indwelling (Fine Wire) Electrodes

It is necessary for recording activity in deep muscles. Fine wire electrodes are the diameter of human hair. They consist of pair of twisted alloy wires, which are insulated except for the tips. They are inserted with a hypodermic needle after being dry sterilized (1 hour at 300 C). The hypodermic needle is withdrawn leaving the wires in place. They are taped at entry to the skin and easily removed after use. The size of the wires (about 0.025-mm diameter) makes them relatively painless. Problems exist for the use of such electrodes in sport. In addition, there are difficulties in locating deep muscles.

There are several limitations to the use of these electrodes. The signal recorded is a function of the length of the exposed tips. The wires tend to deform or even to fracture – the latter may be undetectable but will affect the signal. They have higher electrode resistance than surface electrodes, which requires an amplifier with higher input impedance. There will be some damage to adjacent muscle fibers, which could lead to the recording of the abnormal membrane and action potentials. There is no evidence that they represent muscle activity any better than surface electrodes. Finally, there are ethical issues relating to breakage, possible risks of infection and the use of X-rays to locate the electrodes in the muscle. They are not commonly used in sports biomechanics studies (Bartlett, 1997).

2.2.3. Active Surface Electrodes

These have now been in use for a decade or so, but have only recently become available commercially. Bipolar active electrodes usually have an electrode spacing of 1 cm. They can overcome certain electrical problems and a major advantage of such electrodes is that they require no skin preparation or electrode gels. Disadvantages are the need for a power supply to the electrodes, hence the term active, which might pose health and safety problems. They also increase the overall noise level in the EMG amplification chain. It is probably that their advantages outweigh their disadvantages and that they will become increasingly used in sports biomechanics.

In summary, it may be that surface electrodes are not only safer, easier to use and more acceptable to the subject but, for superficial muscles at least, provide a degree of quantitative repeatability that compares favorably with wire electrodes (Bartlett, 1997).

2.2.4. Electrode Geometry and Placement

The quantity of the electrical activity that can be recorded in a muscle depends on the distance between the electrodes and the active motor units, the area of the recording surfaces of the electrodes are distributed over the muscle. In the analysis of human movement, an EMG is typically recorded with one pair of electrodes (each with a diameter of about 8 mm) that are separated by about 1.5 cm and placed on the skin over the muscle (Enoka, 1994). Experimental results indicate that as much as 50 % less amplitude will be recorded when electrodes lie perpendicular rather than parallel to the muscle fibers (Kamen & Caldwell, 1996; Walthard & Tchicaloff, 1961).

To obtain a more complete record of the EMG for an entire muscle researchers need to use either an array of electrodes distributed over the surface (Chanaud, Pratt, and Leob, 1987; Emerson and Zahalak, 1981; Thusnepayan & Zahalak, 1989; Sited in Enoka, 1994) or an electrode with a large recording area that is placed inside the muscle (Stalberg, 1980; Sited in Enoka, 1994) The latter has been referred to as a macro EMG and is capable of recording most of the muscle fiber action potentials of an active motor unit. The macro EMG has been used to show that the amplitude of motor unit action potentials increases with age (Stalberg & Fawcett, 1982; Sited in Enoka, 1994). For example, the maximum amplitudes of the actions potentials for young subjects (younger than 60) were found to be 595 μV for biceps brachii, 1,068 μV for vastus lateralis, and 1,077 μV for tibialis anterior, whereas for older subjects (older than 60) the maximum amplitudes were 704 μV, 1,611 μV, and 962 μV, respectively. This change results from the loss of motor neurons with age and the peripheral reinnervation of muscle fibers by surviving motor neurons (Enoka, 1994).

2.3. EMG AMPLIFIERS

These are the hearts of an EMG recording system. They should provide linear amplification over the whole frequency and voltage range of the EMG signal. Noise must be minimized and interference from the electrical mains supply (mains hum) must be removed as far as possible. The input signal will be around 0.1 mV for a signal motor action potential (MAP), 5 mV with surface electrodes, or 10 mV with indwelling electrodes. The most important amplifier characteristics are:

2.3.1. Gain

This is the ratio of output voltage. This should be high, ideally variable in the range 100 to 10 000 to suit a variety of recording devices.

2.3.2. Input Impedance

The importance of obtaining a low skin resistance can be minimized using an amplifier with high input impedance that is a high resistance to the EMG signal. This impedance should be at least 100 times the skin resistance to avoid attenuation of the input signal. Minimum input impedances 1 MW for passive surface electrodes have been recommended. Input impedances for high performance amplifiers can be as high as 10 GW (i.e. 1010 W).

2.3.3. Frequency Response

The ability of the amplifier to reproduce the range of frequencies in the signal is known as its frequency response. The required frequency response depends upon the frequencies contained in the EMG signal. This is comparable with the requirement for audio amplifiers to reproduce the range of frequencies in the audible spectrum. Typically values of EMG frequency bandwidth are 10 Hz – 10 000 Hz for surface electrodes and 20 Hz – 20000 Hz for indwelling electrodes. Most modern EMG amplifiers easily meet such bandwidth requirements. Most of the EMG signal is in the range 20 Hz – 200 Hz, which unfortunately also contains mains hum at 50 Hz.

2.3.4. Common Modern Rejection

Use of a single electrode would result in the generation of a two-phase depolarisation-depolarisation wave. It would also contain common mode mains hum. At approximately 100 mV, the hum is considerably larger than the EMG signal. This is overcome by recording the difference in potential between two adjacent electrodes using a differential amplifier. The hum is than largely eliminated as it picked up commonly at each electrode because the body acts as an areal – hence the name common mode. The differential wave becomes three phases (triphasic) in nature. The smaller the electrode spacing, the more closely does the triphasic wave approximate to a time derivative of the single electrode wave. In practice, perfect elimination of mains hum is not possible and the success of its removal is expressed by the Common Mode Rejection Ratio (CMRR). This should be 10 000 or greater. The overall systems CMRR can be reduced to a figure lower than that of the amplifier by any difference between the two skins plus cable resistances. Cables longer than 1 m often exacerbate this problem. For passive electrodes, the attachment of the pre-amplifier to the skin near the electrode site reduces noise pick-up and minimises any degradation of the CMRR arising from differences between the cable resistances (Burdan & Bartlett, 1997).

2.3.5. The Types of EMG Records

Typically we are neither able to record nor interested in recording the action potential of single muscle fiber or motor unit in the analysis of human movement. Most often, scientists measure EMG of many motor units that are concurrently active. This type EMG is referred to as an **interference pattern** because it consists of many superimposed action potentials action potentials (Figure 2.4.). We are often interested in quantifying the interference EMG, and several procedures are available for this purpose. Two of the most common are rectification and integration. As shown in Figure 2.4, **rectification** consist of taking the absolute value of the EMG signal; an electronic module can be used to flip over the negative

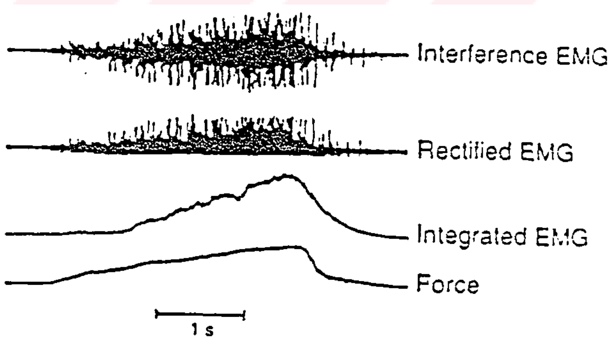


Figure 2.4: An interference EMG is rectified and integrated and the resulting signal (integrated EMG) closely parallels the charge in force.

phases. Then sharp peaks (high frequencies) that are present in the rectified EMG can be diminished by **integration,** an electronic process that consist of smoothing or filtering the EMG to reduce the high frequency content of the signal. After the interference measuring the amplitude of the integrated EMG after the interference has rectified EMG. Comparing the changes in integrated EMG can see the usefulness of this quantification procedure and force in Figure11. To obtain the data in Figure 2.4., we had a subject slowly grade the force from zero to some target value, and we measured the interference EMG and force. After rectification and integration, the EMG paralleled the force record, which suggests that the EMG signal is a good index of muscle force under these conditions (Enoka, 1994).

2.3.6. Interpretation of the Surface EMG

Perhaps one issue that illustrates the difficulty of interpreting EMG results is the topic of amplitude comparison. In as much as the recorded activity can differ as a result of electrode position, skin-electrode interface, or other factors, one recommendation has been to use some procedure to compare the EMG signal of interest some known standard contraction (LeVeau and Andersson, 1992; Sited in Kamen and Caldwell, 1996). The known standard can be the amplitude of the signal in a maximal contraction or in some submaximal contraction at a known force level (Yang & Winter, 1984; Sited in Kamen and Caldwell, 1996). Other reference contractions can be used, depending on the task under investigation. However, there are several problems with this procedure. For example, EMG amplitudes greater than that obtained at 100% maximal voluntary contraction (MVC) can be obtained during dynamic contractions (Hof, 1984; Sited in Kamen and Caldwell, 1996). If EMG-force relationships are the issue of interest, one should recognize that the EMG-force relationship is not always linear, particularly in the higer force reigon (Zuniga & Simons, 1969; Vredenbregt & Rau, 1973; Sited in Kamen and Caldwell, 1996). Different muscle actions are of interest (elbow flexion with and without supination, for example), considerable evidence now supports the idea of task specificity. EMG activity in the elbow flexors may depend on the nature of the task as well as the required force level, and comparision with a standard contraction may produce a biased analysis. Perhaps a feasible is the use of a statistical approach. Jamison and Caldwell (1993, 1994), for example, describe the use of covarience to parcel out between-muscle effects, and the statistical approach may frequently be preferable to the use of standardised contractions (Kamen and Caldwell, 1996).

2.3.7. Reflexive Modulations in Movement Skills

To this point, only one kind of closed-loop processes has been considered: conscious control of actions by sensory information. There are other ways that sensory information is involved in movement control, especially considering the many kinds of corrections, and subtle changes in skills that occurs outside of awareness. The modifications are rooted in the relatively low-level processes in the spinal cord and brain stem and often do not involve conscious control. These modifications are often termed **reflexes,** which are stereotyped, involuntary, usually rapid responses to stimuli. How and under what circumstances these lower-level reflex processes can contribute to skill (Schmidt, 1991).

2.3.8. Stretch Reflex

The two main functions of muscle are to generate power and to react to perturbations. Muscle needs to be spring like in order to react appropriately; the stretch reflex helps the muscle achieve this capability. When a muscle experiences a brief, unexpected increase in length (a stretch), the response is known as the stretch reflex. An example of a stretch reflex is shown in Figure 2.5. In this example, a human subject was grasping a handle that was unexpectedly displaced, resulting in a stretch of the extensor muscles that cross the wrist. The stretch reflex is indicated in the EMG elicited in the extensor muscles. As Figure 2.5 shows, the increase in EMG (response to stretch) begins soon after the onset of handle displacement (stimulus). The stretch reflex consists of at least two components (Matthews, 1991). One component is the short latency response (M1), which is thought to be mediated by a neural circuit limited to the spinal cord (Figure 2.6.). The second component (M2) has a long latency and a more complex origin that may involve the motor cortex in the brain. A third component (M3) is occasionally observed.

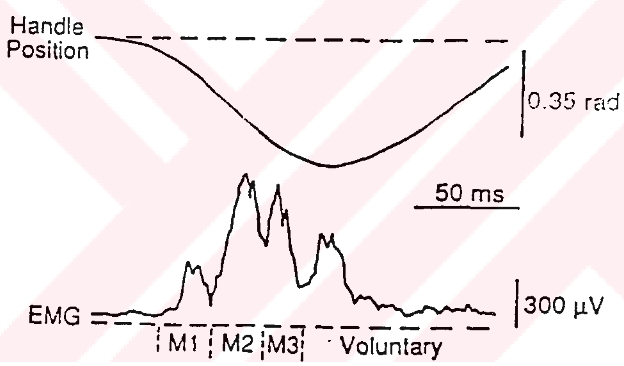


Figure 2.5: A stretch reflex that was elicited by an unexpected stretch (downward) of the extensor muscles that cross the wrist.

For comparison, Figure 2.5 shows that the various components of the stretch reflex all preceded the earliest voluntary EMG, which underscores the ability of reflexes to provide rapid responses to perturbations. Although the latencies for the stretch reflex components vary, the M1 component generally has a latency of about 30 ms, the M2 has a latency around 50 to 60 ms, and the earliest voluntary activity (EMG) begins at 170 ms.

M1 Response: M1 response (or M1 reflex, sometimes called the monosynaptic stretch reflex) is one of the most rapid reflexes underlying limb control. It is caused by the muscle spindles in the biceps being stretched when the load is added, which results in sensory information sent to the spinal cord. After traveling to a single connection (or synapse) in the spinal cord, this information is routed directly back to the same muscle that was stretched, causing the increased contraction seen as the small EMG burst. The latency of this correction is very short because the information involves only one synapse (hence the term monosynaptic) and has a relatively short distance to travel.

The M1 reflex is thought responsible for modifications in muscle contraction caused by small stretches, such as would be associated with postural sways, unanticipated forces and the like. As such the spindle controls muscle length and muscle stiffness (the spring like muscle resistance to length changes when loads are added). These reflex processes are coconscious and are not affected by the number of possible stimulus alternatives that could be presented – that is, M1 responses do not follow Hick's law. Perhaps thousands of these modifications can occur simultaneously in parallel to control functions such as limb position and posture. Because these compensations occur simultaneously, in parallel, nonconciously, and presumably without interference, they do not require attention; they are automatic (Schmidt, 1991).

M2 Response: About 50 to 80 ms after the added load comes a second burst of EMG activity. This M2 response (or M2 reflex, sometimes called the functional stretch reflex or the long-loop reflex) generates more EMG amplitude than the M1 reflex. It has a longer duration, so it contributes far more to movement compensation than the M1. This response also arises from the muscle spindles and travels to the spinal cord, but then the impulses go up cord to higher centers in the brain (the motor cortex and/or the cerebellum). Here the impulses are being sent down the cord and to the periphery to activate muscles at the elbow joint. This greater travel distance and the additional synapses higher levels account for some of the added loop time for the M2.

What are some characteristics of the M2 response? Like M1 response, the number of possible stimuli that could be presented does not affect M2, and thus it does not follow Hick's Law. The M2 is more flexible than the M1, allowing for a few other sources of sensory information to be integrated into the response. One of those sources is the instructional set for the task (information given by the experimenter).

Thus, the amplitude of the M2 response called gain) for a given input can be adjusted voluntarily to generate a powerful response when the goal is to hold the joint as firmly as possible, or it can result in almost no response if the movement goal is to release under the increased load. This capability for modulation is fortune because it allows the limbs to conform to variations in environmental demands.

The M2 reflex is a strange kind of response. It is too fast to be called voluntary, which would require latency near 150 to 200 ms before the beginning of the action. Yet the M2 can be modified voluntarily by conscious processes, such as those associated with the perception of the upcoming moguls in skiing (Schmidt, 1991).

M3 Response: A final type of response to the added load is a voluntary reaction, sometimes called voluntary reaction-time response. Seen as the third burst of EMG activity in Figure 2.5 it is powerful and sustained, bringing the limb back to the final position and holding it there. The latency of the M3 response around 120 to 180 ms, depending on the task and it can affect all of the musculature, not just those muscles that are stretched. The M3 responses are the most flexible of all,

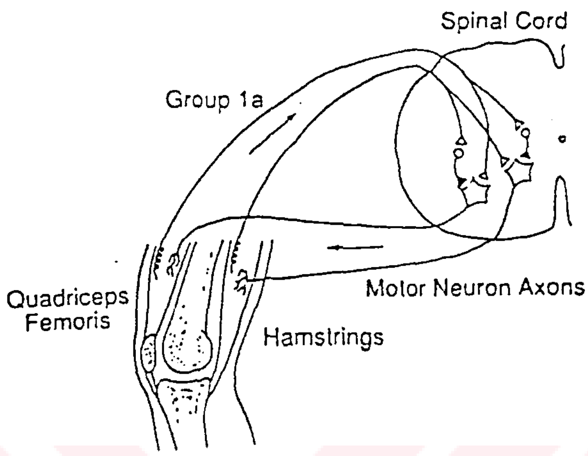


Figure 2.6: Neural circuits underlying the stretch and reciprocal inhibition reflex.

being modified by a host of factors such as instructions, anticipation, and so on. Of course, the delay in the M3 response makes it sensitive to the number of stimulus response alternatives, following Hick's Law. Processes underlying these actions involve the conscious activities resulting in increased reaction time. Because these responses go through the stages of information processing, they occur in a serial fashion and require attention (Schmidt, 1991).

The sensory receptor involved in the stretch reflex includes at least the muscle spindle, both its Group Ia and Group II afferents. The neural circuit involving the Group Ia afferent is shown in Figure 2.6.. Action potentials are generated in the muscle spindle afferents in response to muscle stretch and are propagated centrally to the spinal cord, where they elicit synaptic potentials in the changing conditions (Hammond, Merton, &Sutton, 1956; Sited in Enoka, 1994). Because the stretch can actually be elicited whenever there is an unexpected change in muscle length, it can also occur during movement. If during movement, there is a mismatch between the expected and the actual muscle lengths, this difference may be sufficient to elicit stretch reflex. Under these conditions, however, tendon organs may also be activated, and the Group Ib afferents will transmit their input (inhibitory) to the spinal cord (Matthews, 1990). In human movement, therefore, the unexpected stretch of a muscle can trigger input from many receptors, including the Group Ia, Ib, and II afferents. The net effect is an afferent barrage that can vary substantially from trial even to the extent of failing to elicit a short-latency response (such as occurs when a platform on which a subject is standing is required to restore balance) (Horak & Nashner, 1986, Nashner, 1977; Sited in Enoka, 1994). Furthermore, because of the involvement of the cortex in the stretch reflex (M2 response), the nervous system is able to modulate the response and spread it to muscles that have not been stretched, even to antagonists, if the activity is mechanically appropriate (Matthews, 1991; Sited in Enoka, 1994). The net effect of this flexibility is that both the short and long-latency components of the stretch reflex can be modified to meet the demands of the task.

A response related to the stretch reflex is the **tendon tap reflex** (also known as the tendon jerk). This response is often elicited in clinical settings by striking the patellar tendon with an appropriate implement and assessing the vigor of the contraction. The tendon tap reflex represents a subset of the stretch reflex and involves only activation of the Group Ia afferent and the associated motor neuron output (Matthews, 1990). Because it is based on the monosynaptic connection of the Group Ia afferent, it is a rapid response and has a latency of 25 to 30 ms between striking the patellar tendon and recording the EMG in the quadriceps femoris muscles. The size of the tendon tap reflex is used as an index of the combined effect of muscle spindle responsiveness, motor neuron excitability, and the level of inhibition (presynaptic) acting on the Group Ia afferents in the spinal cord.

2.3.9. Reciprocal Inhibition Reflex

Whereas the unexpected stretch of a muscle can elicit several competitive (excitatory and inhibitory) inputs, the central actions of the input can be diverse. An example of the divergence of the central actions is the effect that the Group Ia afferent input elicits in the motor neurons that innervate the antagonist muscle. As shown in Figure 2.6 the Group Ia afferent branches when it reaches the spinal cord. One of these branches synapses with an interneuron, the **Ia inhibitory interneuron**, which can generate inhibitory postsynaptic potentials in the motor neurons of the antagonist muscle (Day, Marsden, Obeso, & Rothwell, 1984; Katz, Penicaud, & Rossi, 1991). This connection, which serves to inhibit, or lower the excitability of, the motor neurons that innervate the antagonist muscle, is known as the **reciprocal inhibition reflex**. Therefore, activation of muscle spindles in the quadriceps femoris muscle (Figure 2.6.) elicits an excitation of the homonymous (quadriceps femoris) motor neurons but inhibits those for the antagonist (hamstring) muscles. Because the net muscle activity about a joint is due to the difference in activity between an agonist-antagonist pair, the reciprocal inhibition reflex increase the likelihood that the stimulus sensed in one muscle will elicit a meaningful response in that muscle.

One way to test the strength of the reciprocal inhibition reflex in human subject is to have a subject contract one muscle while an experimenter tests the excitability of an antagonist muscle. Carefully shocking the nerve to the muscle and eliciting the Hoffmann reflex can test the excitability of a muscle; a decrease in the reflex represents a decrease in the excitability of the motor neurons innervating the muscle. When a subject contracts the dorsiflexor muscle, there is an accompanying reduction in the Hoffmann reflex of the soleus muscle due to reciprocal inhibition (Shindo, Harayama, Kondo, Yanagisawa, & Tanaka, 1984; Sited in Enoka, 1994). However, because the Ia inhibitory interneuron receives input from a variety of sources, including pathways from higher neural centers (e.g., pyramidal, rubrospinal, vestibulospinal) and proprioceptors, activation of the reciprocal inhibition reflex is not mandatory but depends on the state (level of excitability) of the interneuron (Enoka, 1994).

2.4. EMG CROSSTALK

Few muscles acts in isolation, and the investigation of muscle coactivation or the role of individual muscles or muscle segments in human movement is an important area. Simultaneous activation of agonist and antagonists is more apparent during the early stages of motor learning (Hobart et al., 1975; Sited in Kamen and Caldwell, 1996), during muscular fatigue, and could underlie a means through which joint stiffness is controlled. Coactivation is different in trained atheletes compared with control individuals.

However, any examination of multiple muscle sites, or the determination of the origin of EMG activity, requieres a methodological examination of EMG crosstalk. Because EMG recording techniques require treating the muscle as a volume conductor, the pick up site does not discriminate between signals originating from the underlying muscle, an adjacent synergist, an opposing antagonist, or ambient electrical noise. All such souces will be recorded in direct relation to the amplitude of the signal received at the electrode site.

There are number of different procedures available to measure and identify the existence of EMG crosstalk. Perhaps the simplest procedure is to perform functional resistance tests that isolate specific muscle groups and examine the activity in nonactive muscles (Winter et al., 1994; Sited in Kamen and Caldwell, 1996). Stimulation of the nerve innervating a synergist or antagonist muscle at various intensities will often reveal the extent of volume conduction from adjacent muscle (e.g., Türker & Miles, 1990; Sited in Kamen and Caldwell, 1996). Experiments requiring moderate or high intensity stimulation to record M waves can use double differential EMG to aid in discriminating between distant volume-conducted signals and signals from relevant source muscle (Türker, 1993; Sited in

Kamen and Caldwell, 1996). Pairs of EMG signals in which the existence of crosstalk is suspected can be cross-correlated to examine the interrelationship between the two muscles (Winter et al., 1994; Sited in Kamen and Caldwell, 1996). Signals that are highly intercorrelated either simultaneously or with a time lag attributable to volume conduction delays are frequently assumed to represent an appreciable degree of crosstalk.

The effect of crosstalk can be minimised through the careful use of appropriate procedures (Winter et al., 1994; Sited in Kamen and Caldwell, 1996). Placing pairs of electrodes at least 30 cm apart minimzes the volume-conducted signal. The use of smaller electrodes placed at closer distances also minimzes the overlap between adjacent pairs of electrodes. Recordings made using the double-differential or branched-electrode techniques also minimizing crosstalk (Koh & Grabiner, 1192, 1993; Sited in Kamen and Caldwell, 1996). There are some muscles from which surface recordings may be unattainable without crosstalk interference from other neighboring muscle sources. For example, Benhamou et al. (1995) recently suggested that splenius capitis surface recordings are virtually impossible to obtain without interference from other muscles, particularly the sternocleidomastoid. The use of intra muscular electrodes is advocated in these instances in which EMG crosstalk from surface electrodes is otherwise unavoidable (Kamen and Caldwell, 1996).

2.5. EMG and MUSCLE TENSION

Obtaining a predictive relationship between muscle tension and the electromyogram could solve the problem of muscle redundancy (or muscle indeterminacy). This problem arises because the equations of motion at a joint cannot be solved as the number of unknown muscle forces exceeds the number of equations available. If a solution could be found to this problem, it would allow the calculation of forces in soft tissue structures and between bones. This problem is, arguably, the major issue, which confronts biomechanics. It is not surprising; therefore, that the relationship between the EMG signal and the tension developed by a muscle has attracted the attention of many researchers. Because of the importance of this relationship, this section will briefly summarize some of research findings in this area.

The electromyogram provides a measure of the level of excitation of a muscle. Therefore, if the force in the muscle depends directly upon its excitation, a relationship should be expected between this muscles tension suitably quantified EMG. Varying the number and the firing rate of the active fibres regulates a muscle's tension and the amplitude of the EMG signal depends on the same two factors. It is therefore natural to speculate that a relationship does exist between EMG and muscle. It might further be expected that this relationship only applies to the active state of the contractile elements, and that the contributions to muscle tension made by the series and parallel elastic elements will not be contained in the EMG (Bartlett, 1997).

2.5.1. Isometric Contraction

An isometric contraction is one in which there is hardly any muscle fiber shortening as tension is developed. As there is no change in the angle of the joint there is no bone movement and the origin and insertion remain fixed. An example of this would be carrying a very heavy box in your arms. There is little or no joint movement as the muscles exert the force required to carry the box. Another example would be gripping a tennis racquet (Robertson & Glover, 1989).

A linear relationship has been found between integrated EMG and load up to maximum voluntary contraction (MVC) for the plantar flexor of the ankle. Many later studies have supported these findings (Bartlett, 1997). For example, a linear relationship has been repoted between mean rectified EMG and the force in the first dorsal interosseous muscle. Other investigators have found a non-linear or quadratic relationship between integarted EMG and the muscle tension, for example for the biceps brachii. Many attempts have been made to resolve the discrepancies between linear and non-linear isometric EMG-tension relationships. The possible causes of the discrepancies can be summarised as follows:

1. Technical factors, such as bandwidths of amplifiers, integrators, transducers and recorders; recording method; electrode spacing and positon; durtaion of the integration period; ranges of force; joint position; treatment of results (Kamen et al.,1995; Moritani and Muro, 1987).

2. The spread of activity from neighbouring muscles and variation in the pattern of activity between agonist; simultaneous antagonist activity (Bigland-Ritcihie et al., 1981).

3. The type of muscle: its elastic charastheristics; proportion of different types of motor unit (fibre type is not an important factor) (Komi & Tesh, 1979).

4. Modalities of contraction, for example the level of motor unit synchronisation. With increasing tension beyond the level of a newly recruited motor unit, the latter's firing rate, and hence its contribution to the EMG amplitude, will increase whilst its contribution to muscle tension saturates (Kranzet al., 1983).

5. Individual factors relating to subjects used; age, strenght, endurance.

6. The difference between the muscle volume and electrode detection volume. This leads to a contribution to EMG from newly recruited motor unit within the detection volume that is not linearly proportional to its contribution to the muscle tension. This effect depends on the muscle's size (Burdan & Bartlett, 1997).

7. The control strategy used by the central nervous system varies between muscles. Whlist the first dorsal interosseous recruits all of its motor units below 50 % MVC (maximum valuntary contraction) and has a wide range of firing rates, larger muscles have rapidly increasing and satuarting firing rates and recruit motor units across the whole muscle tension range (Bartlett, 1997).

2.5.2. Isotonic (or dynamic) contraction

An isotonic contraction is one in which the muscle length changes as tension is developed. In an isotonic contraction a consistent load (weight of body, implement being carried and so on) is moved through a range of motion. The muscle exerts varying amounts of tension at different angles of the joints being used, as the same fixed load is moved. In lifting a dumb-bell the elbow flexes. The start of the lifting movement is relatively hard and the greatest tension is developed in the biceps at this point. However, once dumb-bell is moving the muscle does not have to work as hard and tension is reduced. Also the movement is slow to start but is faster as the lift is completed (Robertson & Glover, 1989).

2.5.3. Concentric isotonic contraction

If the length of the muscle shortens during contraction this is called a concentric isotonic contraction. In this case the origin and insertion would come closer together and there is movement of the bone, for example in running, jumping, swimming, football and throwing (Robertson & Glover, 1989).

2.5.4. Eccentric isotonic contraction

An Eccentric isotonic contraction is one in which the muscle lengthens while tension is developed, and is generally used in resisting gravity. Eccentric contractions generally involve lowering of the body or body parts against the forces of gravity. An example of this would be the lowering of the body in a chin-up. The biceps must develop tension to lower the body so that it does not 'flop' down and at the same time they must lengthen to allow the arms to straighten in a controlled manner. Another example would be the slow adduction of the arm from a horizontal position. Here the deltoid is performing an eccentric contraction, gradually lengthening, against gravity (Robertson & Glover, 1989).

2.5.5. Isokinetic Contraction

During an isokinetic contraction the tension developed in the muscle is maximal throughout the entire range of motion. As the muscle shortens the resistance to the movement is increased so that the tension developed in the muscle is constant at all joint angles and the speed of movement is constant.

Because isokinetic contractions exercise the muscle maximally through its entire range of motion they are now considered the most effective for developing muscular strength and endurance in athletes. However, it should be noted that to perform isokinetic contractions one needs to access to specialized exercise machines, such as those of the Cybex and Nautilus range (Robertson & Glover, 1989).

A linear relationship has been between iEMG and Achilles tendon force at slow constant speed, and a linear relationship between speed and FWRI when force was constant with little change of FWRI with speed for lengthening contractions.

There are difficulties in applying the results of EMG studies of isometric or very slow contractions to dynamic, voluntary movements. These typically last only a few tenths of a second, involve less than ten impulses for any given motor unit, and have different patterns of firing than during sustained contractions.

The discrepancies that exist between research studies even for isometric contractions should not lead one to expect a simple relationship between EMG and muscle tension for the fast voluntary contractions that are characteristic of sports movements. For such movements, the relationship between EMG and muscle tension still remains elusive although the search for it continues to be worthwhile (Bartlett, 1997).

2.5.6 Twitch Contractions

The mechanical response of a muscle fiber to a single action potential is known as a twitch. Following the action potential, there is an interval of a few milliseconds, known as the latent period, before the tension in the muscle fiber begins to increase. During this latent period, the processes associated with excitation-contraction coupling occurring. The time interval from the beginning of tension development at the end of the latent period to the peak tension in an isometric contraction is the **contraction time**. Not all the skeletal muscles fibers have the same contraction times. Some fast fibers have contraction times as short as 10 ms, whereas slower fibers may take 100 ms or longer (Vander at. al., 1990).

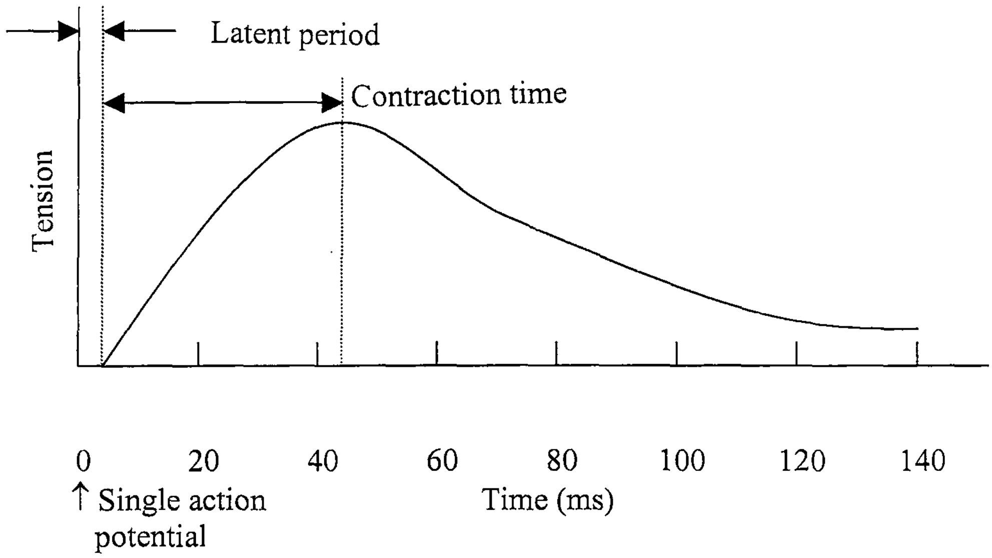


Figure 2.7: An isometric twitch of a skeletal-muscle fiber following a single action potential.

2.6. CONCLUSION

The interpretation of the surface EMG has been debated for more than 50 years since Denny-Brown published his monograph on the topic (1949). Although many of the early questions have been resolved, the number of controversial issues remains sizeable. Similar to the problem of recording EEG from a bowl of lime Jell-O, the interpretation of EMG activity is frequently subject to error. Nevertheless, with considerable care and caution, the EMG signal can be a highly useful tool for clinical diagnosis, treatment, and research (Kamen and Caldwell, 1996).

2.7. MUSCULAR ANALYSIS OF RELEASE PHASE IN ARCHERY

Releasing the arrow properly is the most important fundamental of shooting. The key muscle force component of the release is the final one-eighth inch movement archer's arrow through the clicker prior to release (McKinney & McKinney, 1997). The sequences of the releasing movement by high-speed camera analysis in skilled subject are shown in Figure 2.7 from 25 m sec before release, the fingers begin extension (Nishizono, 1996). When the clicker heard, the joints of the

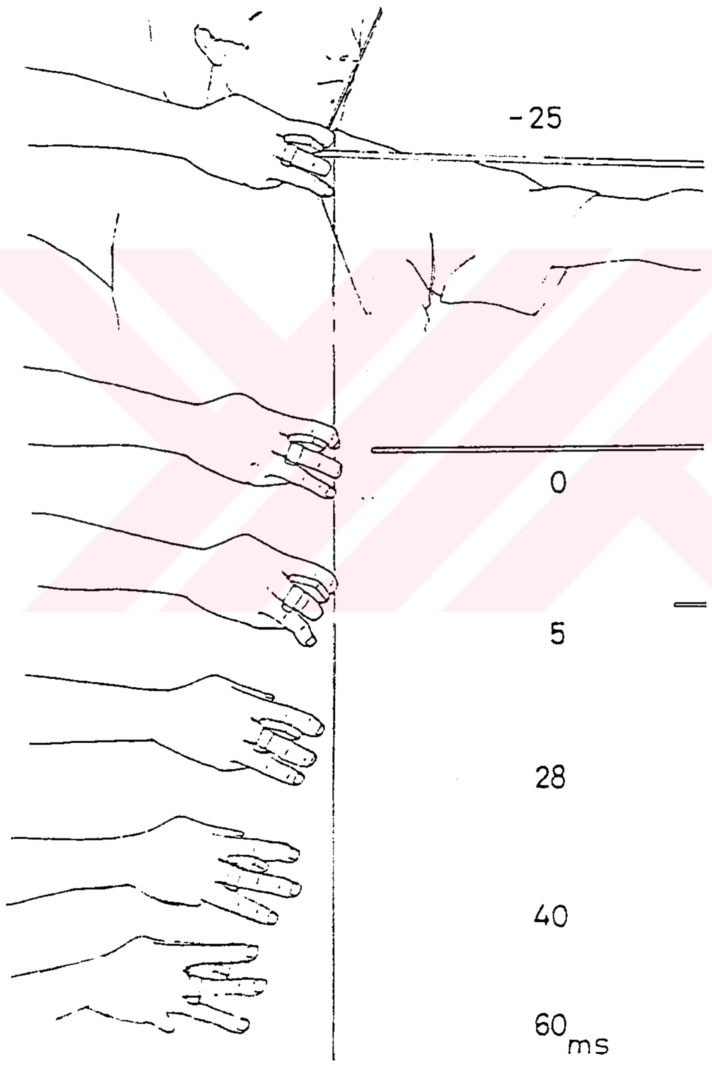


Figure 2.8: The traces of the release movement in skilled archer from a high-speed camera analysis. The time of release is 0 m sec. from 25 m sec before the release, the fingers begin extension.

string fingers are ready to extend, allowing the bowstring to move forward and the arrow to release (McKinney & McKinney, 1997).

McKinney (1997) suggested that the extension of string finger joints is not the result of forceful finger extension muscle contraction by musculature in fore arm and hand. The external force for release is caused by the string as archer relaxes the tension within the finger musculature, that is, relax the "three-finger hook" around string.

In contrast, some results do not support the popular teaching tenet that a simple relaxation mechanism, nor the notion that a relaxation mechanism is superior to one involving a more active response of finger extensors achieves bowstring release by successful archers. Consequently, it is concluded that success in archery can be achieved with either of these muscle activation patterns. The small intra-individual variations in the activation patterns of the flexor and extensor digitorum muscles that it may nor be the mechanism that distinguishes archers of different skill level, but rather their ability to reproduce a particular mechanism consistently from shot-to-shot (Martin et al., 1990).

2.7.1. Forearm Anatomy

Sport skills and other exercise activities require the use of all these joints: flexion or extension of the elbow joint, pronation or supination of the radioulnar joint, flexion or extension and abduction and adduction of the wrist and hand. A large number of muscles are used in these movements. In each wrist and hand there are 30 muscles, of which 15 are intrinsic (inside) muscles (Thompson, 1985). In this section the muscles, which are related with the release phase in archery, will be discussed (Wells, 1971; Luttgens &Wells, 1989):

Extensor Digitorum: Being an extensor of the interphalangeal joints, the extensor digitorum is an important wrist extensor (Luttgens & Wells, 1989). It origins from the lateral condyle of the humerus (Thompson, 1985) inserts to four tendons to the four fingers (Wells, 1971). Each tendon divides into three slips, the middle one attaching to the dorsal surface of the second phalanx and the other two uniting and attaching to the dorsal surface of the base of the distal phalanx. It can be palpated at the dorsal surface of the forearm (Figure 2.8.).

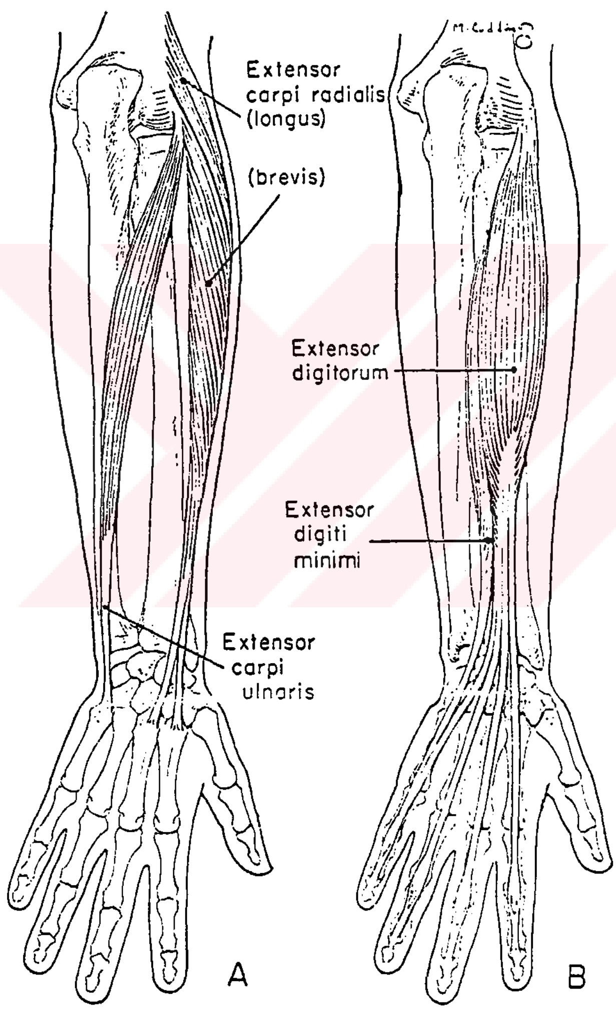


Figure 2.8: Muscles on back of the right forearm. A shows extensor carpi radialis longus and brevis and extensor carpi ulnaris. B displayes extensor digitorum and extensor digiti minimi.

This muscle does the action of extension of proximal phalanges of fingers; assists in extension of second and third phalanges and of wrist (Wells, 1971). And also it contributes to the extension of elbow (Thompson, 1985).

Flexor Digitorum Superficialis: This muscle is active in wrist flexion as well as flexion at the proximal phalangeal joint (Luttgens & Wells, 1989). The origin of the muscle is the humero-ulnar head at the medial epicondyle of the humerus, ulnar collateral ligament, medial margin of the coronoid process and the radial head at oblique line on anterior surface of radius (Wells, 1971). It ends by

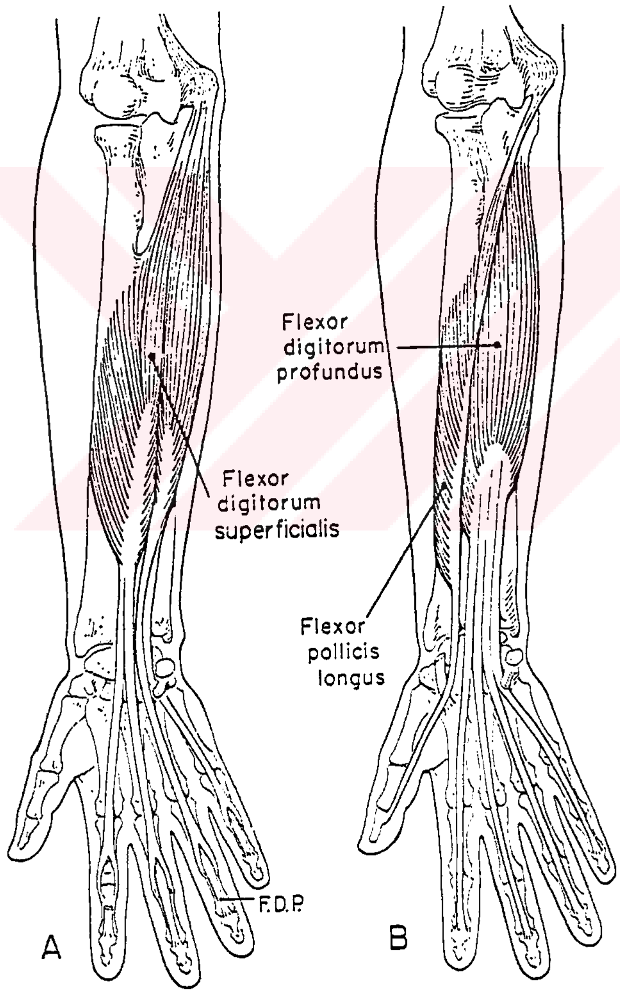


Figure 2.9: Deep muscles on front of right forearm. A shows flexor digitorum superficialis; B displays flexor digitorum profundus and flexor pollicis longus.

four tendons to the four fingers, each tendon splitting to the sides of the base of the middle phalanx (Wells, 1971). It can be palpated at the palm of the hand (Figure 2.9.).

Flexor digitorum superficialis muscle does the flexion of middle phalanges of fingers; assists in flexion of the first phalanges and of the wrist.

Reaction and Movement Speed

An important behavioral characteristic in which individuals differ greatly is the speed of reaction (Oxendine, 1968). The speed or quickness with which a performer can respond is one of the characteristics associated with skillfulness in activities requiring fast execution of the movement (McKinney, 1985). This component seems strategic in distinguishing between outstanding, average, and poor performers in many motor skills. Athletic coaches have traditionally assumed that the best athletes are those with the fastest reaction time. For this reason, they have shown considerable interest in the speed of reaction and in determining the performers who can move most rapidly. Experimental psychologists have also exhibited a great deal of interest because reaction speed is one of the important response variables among people and because it is conveniently available for rather objective measurements (Oxendine, 1968).

Reaction Time Versus Movement Time

Several meanings are often attached to the term "reaction time". Some people use it in reference to such traits as the ability to get quick starts, i.e. to take the first few steps most rapidly, or to have quick movements. Others have a more limited concept of the term. For the measurement of reaction time, some physical educators and psychologists have restricted the subject's response to small, finger movements. Occasionally, large motor responses have been used. To clarify the issue, reaction time and movement time will be discussed as components of speed of reaction (Oxendine, 1968).

Speed of response (the total time or respond) involves both reaction time and movement time. The time between the presentation of a signal to which to respond and the beginning of that response defines reaction time (McKinney, 1985). *Reaction Time* is the period from the stimulus to the beginning of the overt response. It is not the term might seem to imply, i.e., the occupied by the execution of the response. Rather reaction time is the time required to get the overt response started, or the stimulus-to-response interval. Following the stimulus, there is a latent period while the impulse is transmitted from the sense organ to the central nervous system and then backs to the muscles. The muscles must then contract to begin movement. Although all of these actions take some time, the most time is probably taken in the motor areas of the brain. This is especially true if any decision-making is required. According to Woodworth and Schlosberg (1968), reaction time includes: *sense-organ time, brain time, nerve time and muscle time.* In experimental situations the measurement of reaction time has involved some simple response such as releasing a button or telegraph key. Since even these small responses require some movement through a distance, they are not "pure" measures of reaction time. But they have been acceptable as reasonable accurate (Oxendine, 1968).

In addition to reaction time, movement time has been of special interest to athletic coaches and physical educators. Experimental psychologists, on the contrary, have not investigated or discussed this component widely. *Movement Time* refers to the period from the beginning of the overt response to the completion of a specified movement. In the measurement of movement time, a rather large movement is usually employed. The total movement response, therefore, encompasses both reaction and movement times; reaction time being the stimulus-response interval, and movement time being the period required for the response itself. The term "reaction time" has occasionally been used erroneously to include both of these concepts, even when the movement phase is quite long.

It has traditionally been assumed that there is rather high relationship between reaction time and movement time. That is, the individual with a fast reaction time was believed to be able to move more quickly or to run faster than a person with a slower reaction time. This particular question has been investigated quite thoroughly during the past few years. As a result of this research, considerable doubt has been cast the traditional assumption (Oxendine, 1968).

Guilford (1958) classified *impulsion* (the rate of starting movements from a stationary position) and muscular strength as general factors, which are primarily dependent upon heredity. *Speed* (the rate of movement after it is initiated), static precision, dynamic precision, coordination, and flexibility are listed as traits which seem to be dependent upon experience. According to Guilford, therefore, simple reaction time (impulsion) is inherited, while the movement phase of reaction time (speed) is developed. This would suggest little, if any, relationship between the components of reaction and movement time (Oxendine, 1968).

Henry (1961) stated, muscular force causes the speed of a limb movement, whereas reaction latency reflects the time required for a pre-movement operation of a central nervous system program-switching mechanism. Movement time, on the other hand, is caused by muscular force. On the basis of these concepts and his research, he suggests a zero correlation between the two traits. This is contrary to the widespread beliefs of some coaches and physical educators (Oxendine, 1968).

Another question, which has been investigated during recent years, is the *generality of reaction time,* i. e., do people who have fast reaction with the right hand also have fast reaction with the left hand, the feet, or other part of the body? Evidence regarding this topic is rather inconsistent. Seashore and Seashore (1941) reported a high correlation among the reaction time of hands, feet, and even biting movements. In their study, the speed of hands did not differ greatly from each other, nor did the speed of the feet. These correlations demonstrated a high degree of individual consistency. However they did show that foot movement was slower than hand movement. Rangazas (1957) also reported hand movement to be faster than foot movement. After an extensive study with children between the ages of seven and thirteen, McArthur (1957) differed with Seashore and Seashore's assumption of generality in bodily movement speed. He found no relationship among the movement speed of various parts of the body, or among different types of movement (Oxendine, 1968).

Simple and Choice Reaction Time

In the literature and in discussions of speed of reaction, a distinction is made between simple reaction time and choice reaction time. *In simple reaction time* testing, the individual may be asked to make a simple response, such as depressing or releasing an electric key or switch when light goes on. Under these conditions, one type of stimulus is given, and one response is solicited. When the stimulus of light is used in such an experiment, reaction time will generally be in the vicinity of .20 to .25 seconds. If a buzzer or another stimulus is used, the time will be slightly less. These times are relatively fast because there are no alternatives, which the subject must consider. He knows in advance what stimulus to expect (Oxendine, 1968).

In *choice reaction time,* there are alternatives for the subject to consider. Other terms used in reference to this type of response are discriminative or *disjunctive* reaction. It might be that a red light requires the depression of key 1, while a green light requires the depression of key 2. In such an experimental of choice reaction, the stimuli are alternated in an irregular order. The subject therefore, must observe the stimulus and make a choice of which response is appropriate. Needless to say, the time for choice reaction is slower than that for simple reaction. The choices might vary from two to five or ten. It has been found that the greater the number of choices, the slower is the reaction (Oxendine, 1968).

There is no doubt that there are *individual differences* in reaction time. All researchers report differences among individuals, whether the testing is on simple reaction, choice reaction or movement time. Within individuals, however, there are number of factors which contribute to speed of reaction (Oxendine, 1968).

Reaction to a signal, whether it is one requiring simple reaction time or choice reaction time, always consumes time. The time required is explained by the need for the stimulus (signal) to stimulate the appropriate sensory organ (visual, auditory, or cutaneous), pass over nerve tracts to the brain, and return over nerve tracts to the muscle(s) to be activated. Information processing models describe the process as receiving the stimulus, interpreting it, deciding on what to do, and, then executing the action (McKinney, 1985).

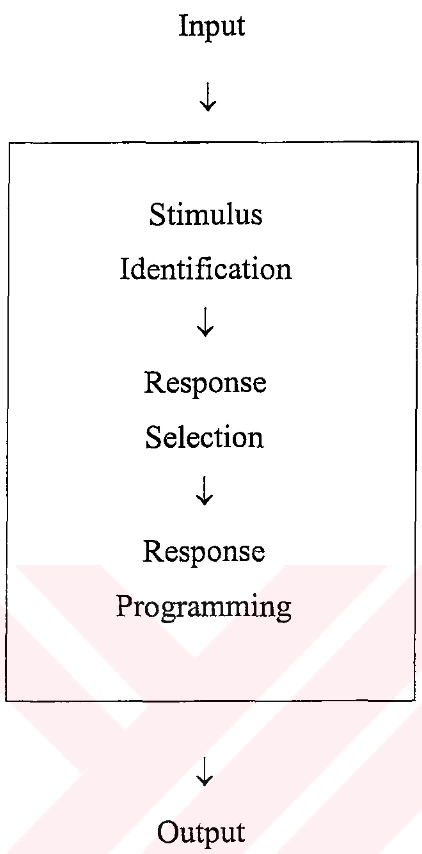


Figure 2.10: The expanded information processing model showing the stimulus identification, response selection, and response programming sub stages (Schmidt, 1991).

CHAPTER 3

3. MATERIALS AND METHOD

The first aim of this study is to analyze the activation strategies of forearm muscles in the bow hand by means of EMG records synchronized with clicker sound among Turkish archers and non-archers. The second aim of this study is to test the validity and reliability of the device called ClickRT as a part of Archery Chronometer.

3.1. Subjects

	Elite Archers		Beginner Archer		Non-Archers	
	Male	Female	Male	Female	Male	Female
Number	5	5	5	5	5	5
Age	21.8±3.4	24.8±2.5	17.3±2.5	16.6±3.2	28.2±4.2	24.4±3.7
FITA Scores	1296±43	1322±24.7	1157±35	1147±40.2	-	-
Training Age	8±0.7	10±1.1	5±0.6	4±0.4	-	-

Table 3.1: Subjects

Three different subject groups were involved in this study. The first group include 5 male and 5 female Turkish Natioanal Team archers. For the second group (beginner archers), 5 male and 5 female volunteered for this study from Ankara Archery Club. Finally for the third group 10-university student or stuff, 5 male and 5 female, served as the non-archers group. The ages, FITA scores and training ages are given in the Table 3.1.

3.2. Collecting the Data

3.2.1 EMG Measurement System

To measure electrical activity in the forearm muscles (flexor digitorum superficialis, extensor digitorum) by means of EMG, OCTOPUS Analog Multiplexed cable Telemetry 8 channel device (AMT – 8) was used. The OCTOPUS is a system designed to acquire and transmit EMG signals from animal or human (isolated version) subjects to an arbitrary computer to tape recorder based acquisition system or multi-channel monitoring device. Standard system is comprised of three main components:

1. Patient Unit with eight APE 500 (Amplified Probe-Electrode) + battery pack
2. 10 m long transmission cable
3. Receiving Unit (rack or table top)

3.2.1.1 APE 500 - Amplified Probe-Electrode

The APE 500 is a high impedance differential amplifier with gain 500. The main purpose of the probe-electrode is to enable connection of pellet electrodes residing on the muscle to the Patient Unit, amplification of the electromyogenic signals and conversion of high impedance, which totally eliminates “cable noise”. The APE 500 has pellet electrode clips on one end, and a flexible cable on the other end, which terminates in the Patient Unit connector (Figure 3.1).

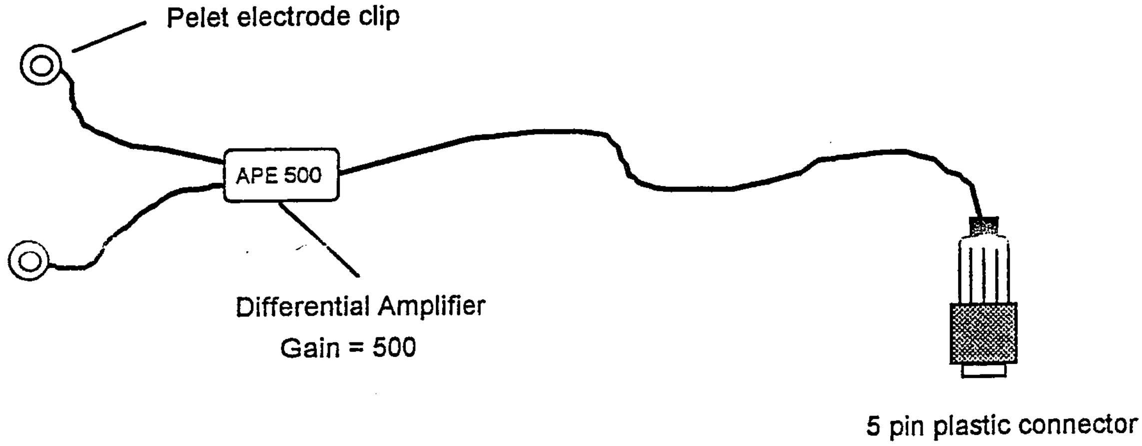


Figure 3.1: Ape 500 Probe-Electrode with fixed gain = 500.

3.2.1.2 Patient Unit

The Patient Unit is a small plastic box, which is usually attached to the subject by fastening the harness around his or her hip. The main function of this unit is to encode incoming signals from the APE 500 probe-electrodes (the default gain setting is G=500) and to transmit them via a single cable and a single signal line to the main receiving unit, where further gain control is available. There are no adjustable components on the patient box, which are accessible to the user, and therefore no errors can be made due to unintentional touching or tampering (Figure 3.2).

Low Battery Indicator: A red signal light at the upper edge of the case will light when the voltage of the batteries reaches levels where transmission reliability could be degraded. The low battery indicates that the batteries should be changed within typically 5 minutes of further operation.

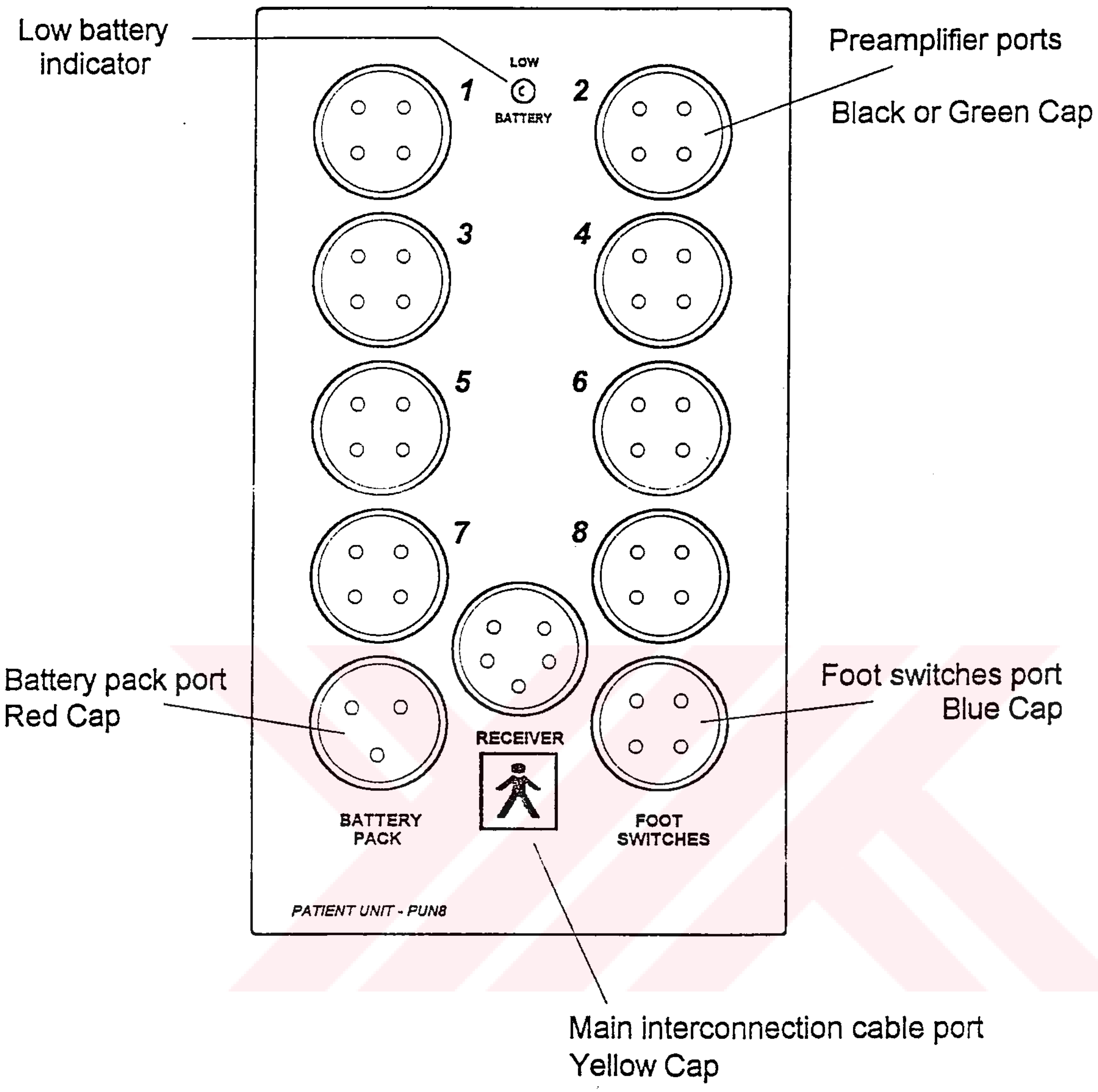


Figure 3.2: Patient Unit

5 pin APE 500 connectors: The eight plastics 5 pin round connectors marked 1 to 8 (black color) is the ports where you plug in the APE 599 electrodes. Any combination of the 8 available channels can be used.

5-pin connector "RECEIVER": The connector at the lower edge of the case marked as RECEIVER serves to connect the Patient Unit via the supplied cable to the Receiving Unit (rack mount or tabletop).

Receiving Unit: On Figure 3.3 is the front panel of the main Receiving Unit. The Receiving Unit receives the signals transmitted from the Patient Unit and provides necessary signal decoding, processing and further amplification.

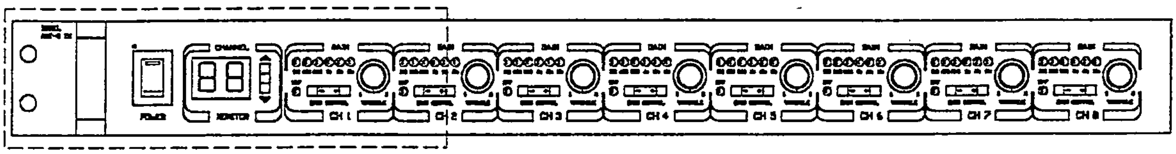


Figure 3.3: Front panel of the Receiving Unit (the dashed line marks the area enlarged in Figure 3.4).

Power Switch (1): The main power switch (~110V/60Hz or ~240V/50Hz) resides on the left side of the front panel and is the main power switch for the Receiving Unit.

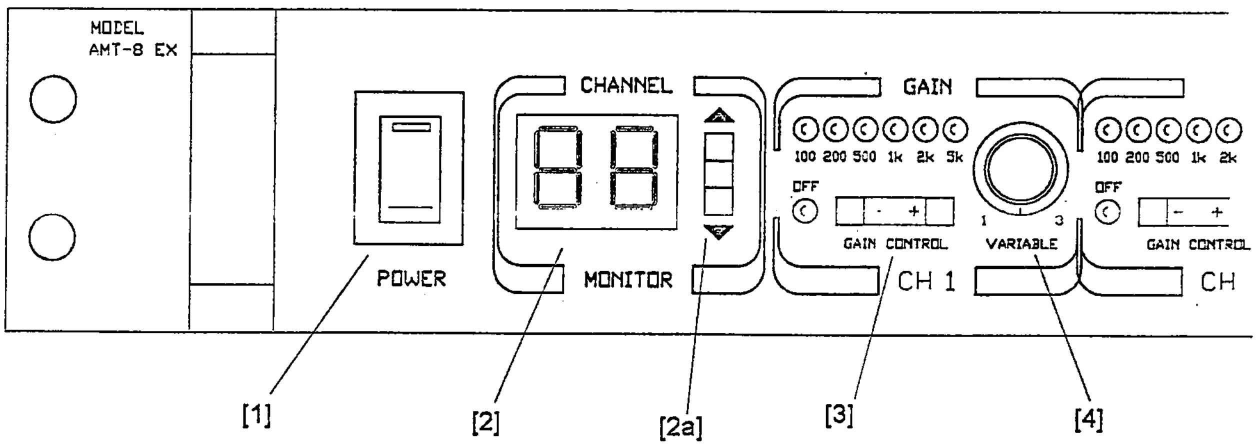


Figure 3.4: Front panel of the Receiving Unit, enlarged portion of Figure 3.3.

Channel Monitor (2): The channel monitor enables you to monitor ("tap") any of the output channels without removing the BNC connectors on the rear panel. The number shown in the small window display indicates which channel is currently selected for monitoring. One can select the desired channel to be monitored by pressing the key switches (2a).

Gain Control (fixed steps) (3): Six fixed gain steps (settings) are available: G=100, G=200, G=500, G=1000, G=2000, G=5000 indicated by green LEDs. One can disable he channel by selecting the "OFF" mode. A red LED indicates this state.

Variable Gain (4): The variable gain option provides additional, continuous gain control. The variable gain values range from 1 to 3 in variable mode and provide additional gain of up to 3x, so that the total gain range of the OCTOPUS system is from 100 to 15000.

3.2.1.3 The Rear Panel

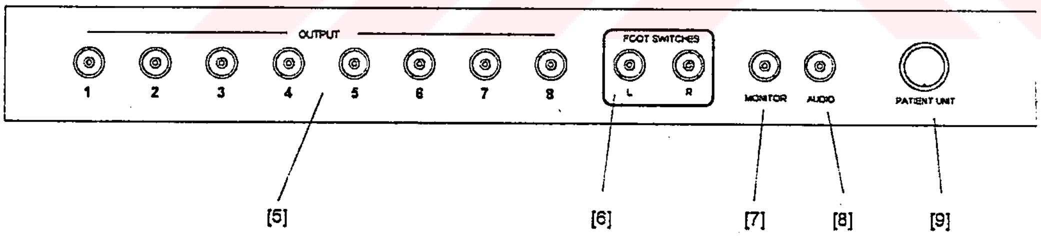


Figure 3.5: Rear panel outline

Channel Outputs (5): Eight analog outputs are provided on the rear of the Receiving Unit marked from 1 to 8. Standard BNC connectors are used to allow simple and trouble free interconnection with the user's signal processing or data acquisition system. The maximum undistorted level output is in the range of +/- 2.0 Vpp. A short circuit protection is built into each channel output.

Foot Switch (6): The foot switch output is a TTL level (digital) marker signal available for synchronization purposes. Two independent channels are available. It is possible to select between two distinct modes of the foot switch operation.

a. continuos mode

b. constant time pulse mode

Factory setting is a continuous mode by default. It is possible to change this mode by simple repositioning of the two jumpers inside of the main receiving unit.

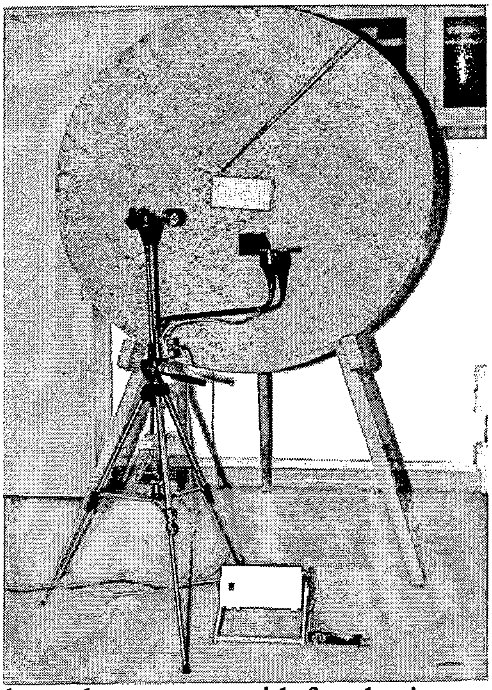
Monitor (7): The monitor output (MONITOR) is designed for signal monitoring. Any one of the eight channels can be routed to this output and observed on an oscilloscope.

Audio (8): The audio BNC connector is internally connected to the monitor circuitry via a 20 dB attenuator that enables direct connection to any standard audio equipment (amplifier, tape deck or receiver) and thus convenient audio monitoring of the selected channel.

PATIENT UNIT connector (9): The main transmission cable receptacle. The other end of the cable is to be plugged in the patient unit.

3.2.2 Archery Chronometer

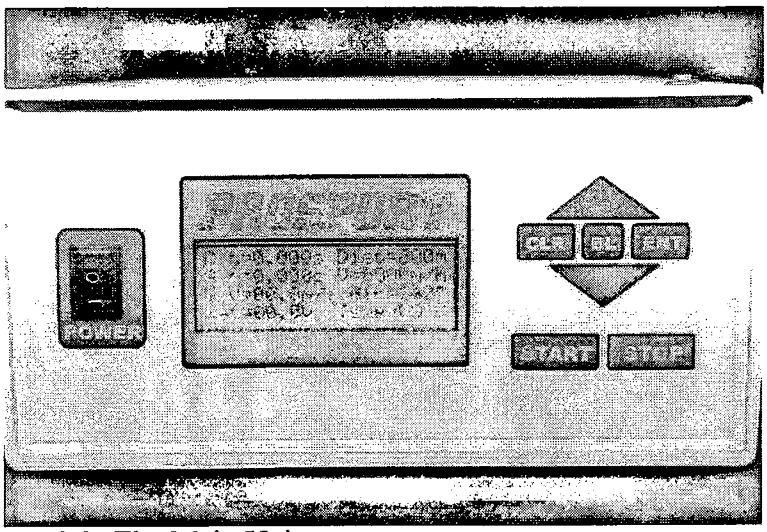
Special design device (Prosport TMR ESC 3100 Archery Chronometer) has the following four main parts: (1) Main Unit, (2) Clicker Reaction Time measurer, (3) Wind Speed and Direction Measurer, and (4) Vibration Sensor (Picture 3.1).



Picture 3.1: Archery chronometer with four basic parts.

3.2.2.1 Main Unit:

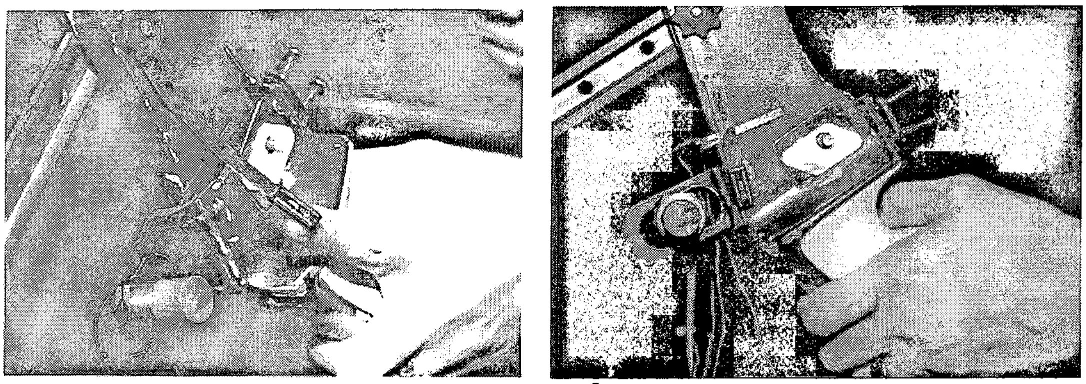
Seven different measurement results can be displayed on the main unit screen. (1) Clicker Reaction Time (Ct), (2) Average Flying Time (At), (3) Velocity of the arrow (V), (4) Wind Velocity (WV), (5) The Direction of the Wind (dir), (6) Battery Indicator (Bat), and (7) The Temperature measurer. Results can be seen at the same time on the screen (Picture 3.2). The device can make the measurement with 0.1 % of second sensitivity and 0.01 % error.



Picture 3.2: The Main Unit.

3.2.2.2 Clicker Reaction Time (ClickRT) Measurer

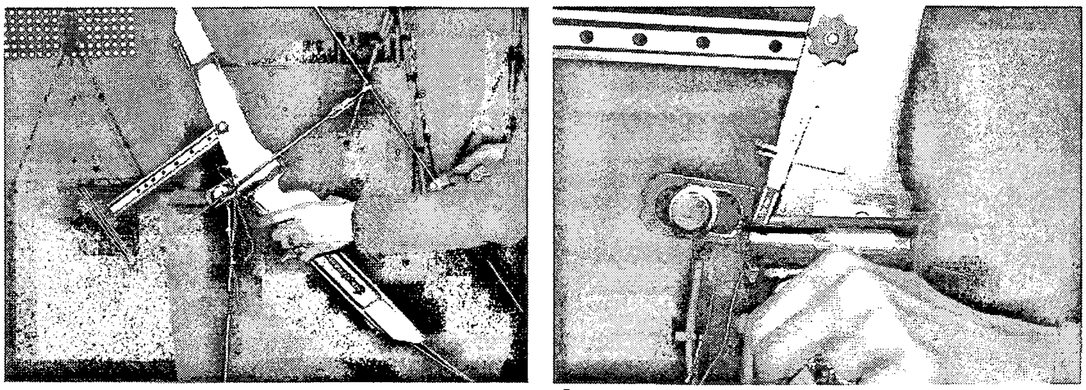
Two heads of the conductor metal are placed under the clicker (one is attached under the clicker and the other is placed on the bow handle) (Picture 3.3.a). In addition to this, a sensor (weighting 150gr and sensitive to metal) is placed on the bow handle, 1.5 cm away from the clicker (Picture 3.3.b).



a. **b.**

Picture 3.3: Placement of the Clicker Reaction Time Measurer on the bow handle.

During the Clicker Reaction Time Measurement, the arrow is placed under the clicker as all of the archers do in the World for every shot (Picture 3.4.a). The archer starts drawing the bowstring as the arrow is placed under the clicker.



a. **b.**

Picture 3.4: (a) the placement of arrow on the bow, (b) reaching the final position in arrow shot movement.

When he/she reaches the final position (Picture 3.4.b), the clicker snaps against the bow handle (Picture 3.5.a). The chronometer starts counting when the clicker falls from the point of the arrow and brings two heads of the conductor metals together. As soon as the archer hears the sound from the clicker, he/she releases the bowstring by opening the three-finger hook of the drawing hand. The arrow is pushed forward by the bowstring powerfully. The point of the arrow covers 1.5 cm distance and passes in front of the sensor. The sensor stops counting after sensing the metal point of the arrow (Picture 3.5.b). This time gap is called as Clicker Reaction Time (ClickRT) by Ertan at. Al. (1996).

a. b.

Picture 3.5: (a) the clicker falls from the point of the arrow, (b) the metal point of the arrow passes in front of the sensor that is sensitive to metal.

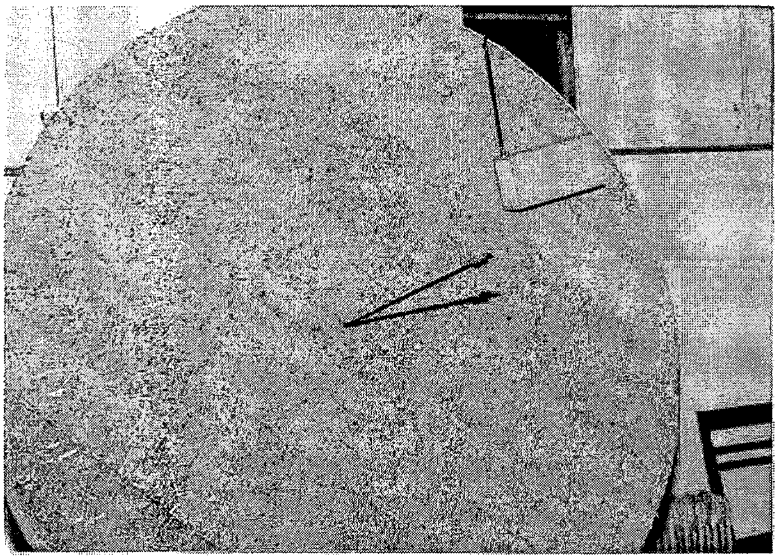
3.2.2.3 Wind Speed and Wind Direction Measurement

Wind Speed or Velocity (WV) is measured in m/sec and the Direction of the Wind (dir) is measured in degrees. The WV and dir measurers are attached to the main unit with a 40-m cable. It is placed at the midpoint of the shooting distance and parallel to the shooting line on the 35th m of the shooting distance. The device continuous measuring wind velocity and wind direction during the shot. As soon as the clicker snaps the chronometer starts counting the wind velocity. The direction is displayed on the screen at the same time with the arrow release (Picture 3.1).

3.2.2.4 Average Speed and Flying Time Measurement

There are fixed distances for female and male archers according the FITA rules (FITA, 1996). At the beginning of the measurement, the researcher sets the shooting distance manually that the arrow will be shot (Picture 3.2). The flying time measurement starts with the end of the ClickRT. As the metal point of arrow passes to the front of the sensor, the ClickRT measurement (Picture 3.5.b) ends and the Flying Time (At) measurement starts.

When arrow covers the given distance, it hits the target and causes vibration on it. There is another sensor detecting vibration and sending stimulus to the main unit telemetrically. The main unit stops the second chronometer by sensing the vibration (Picture 3.6). Researcher can measure the flying time by this way in a given distance. If one knows the flying time in a given distance, he/she can calculate the average speed of the arrow.



Picture 3.6: The ending of the Average Speed (V) and Flying Time (At) Measurement.

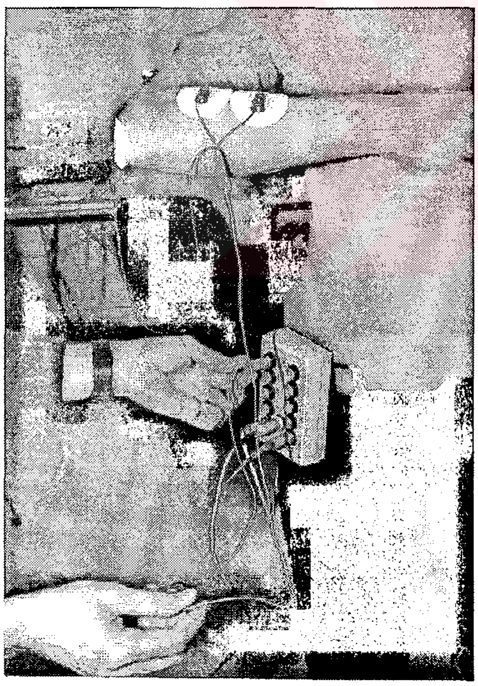
3.3 Data Collection Procedure

3.3.1 Data Collection Procedures for Validity Testing and Muscular Analysis

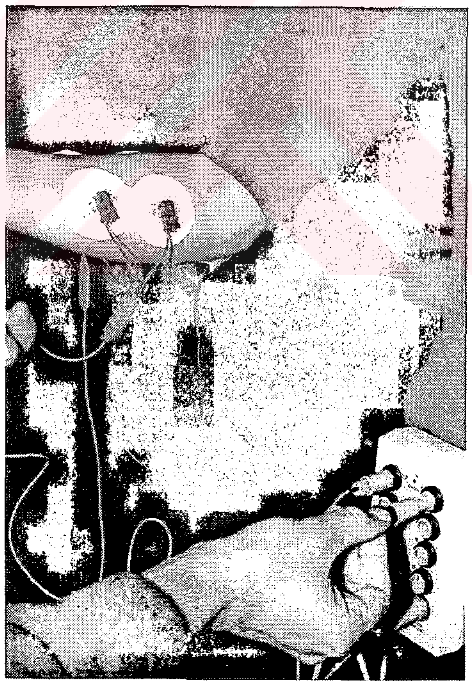
All the measurements were taken between the dates of July 1 – August 15 2000. Each subject participated in a single test session in the Biomechanics Laboratory of the Mechanical Engineering Department at the Middle East Technical University, during which the electromyographic (EMG) activity of flexor digitorum superficialis and extensor digitorum muscles were quantified using surface EMG techniques and the OCTOPUS EMG Cable Telemetry System. ClickRT were measured at the same time with the EMG measurement. These two-measurement methods were synchronized with each other. First, archery chronometer was placed on the bow handle, then a foot switch was attached under the clicker. These two systems were isolated from each other in order to avoid cross-talk effect between measurement devices (Picture 3.7).

Picture 3.7: The placement of Clicker Reaction Time Measurer and Foot Switch together on the bow hand under the clicker.

Palpating the desired muscles as the subjects simulated the shooting position and performed maximum isometric contraction of these muscles (flexor digitorum superficialis and extensor digitorum muscles), the researcher identified recording sites on the drawing arm. The recording sites were prepared first by shaving the region and then lightly abrading and cleansing the area with alcohol. Skin tack F55 electrodes, filled with conductive electrolyte, were then positioned longitudinally over each muscle (the electrode distance was approximately 2 cm). The reference Electrode was placed on the Olecranon Process of the Ulna on the drawing arm. The first channel was used for the recording the extensor digitorum muscle's activity (Picture 3.8.a). The second was used for the recording of the flexor digitorum superficialis muscle's activity (Picture 3.8.b).



a.



b.

Picture 3.8: (a) the placement of Electrodes on the extensor digitorum muscle, (b) the placement of Electrodes on the flexor digitorum superficialis muscle.

To detect if there was any cross talk effect, online measurement of a single muscle was used after placing the electrodes. First, the researcher opened the online measurement of the first channel whose electrode was placed on the extensor digitorum muscle. Then the subject was asked to open the fingers (fore, middle and ring fingers) to bring them to the extension position by an isometric contraction to a stable resistance (Picture 3.9.a).

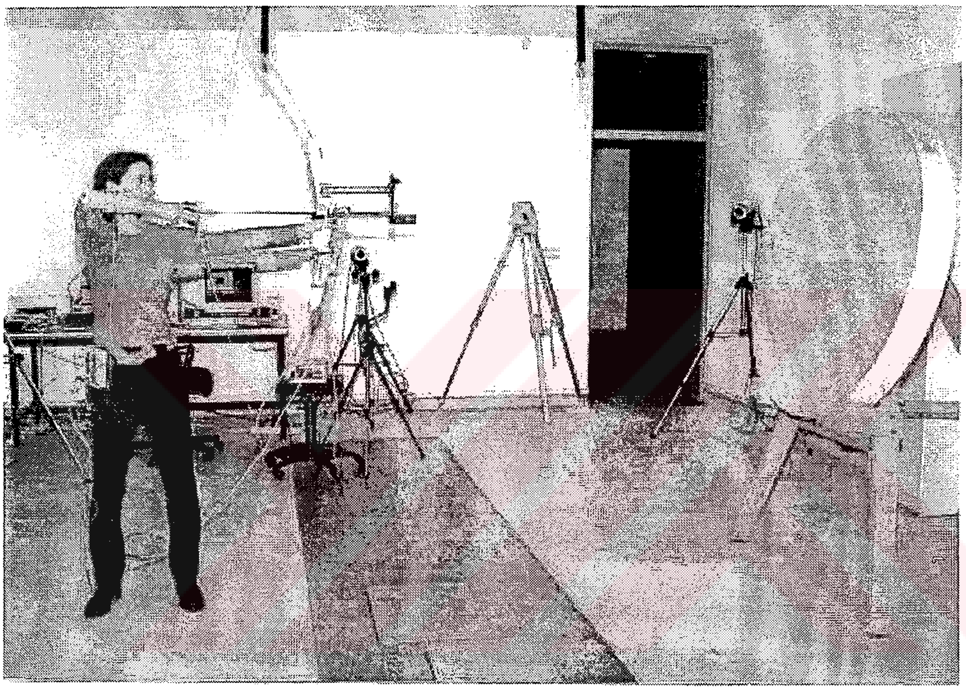
a. **b.**

Picture 3.9: (a) a test for the first channel for extensor digitorum muscle, (b) a test for the first channel for flexor digitorum superficialis muscle.

After that the subject was asked to make maximal flexion with three fingers again for the first channel online measurement (Picture 3.9.b). If there were no electrical activity measured on the screen, it would be considered, as there was no cross talk effect. This examination was tried for the flexor digitorum muscles in all the subjects in the same way.

Once it was determined that acceptable signals were being recorded, each subject completed three trial shots both to check whether the two systems working or not and to give chance to archer to adapt his or herself to the real measurement conditions.

Following a brief rest period, the muscle activity was sampled. EMG sampling was for a 5-s period as the subjects completed 12 shots. The subjects shot three arrows, then had a three-minute rest period. For the shooting trials, the sampling was manually triggered, shortly after the archer achieved a full draw position, such that the release of the arrow occurred at approximately the midpoint of the sampling period (Picture 3.10).



Picture 3.10: Starting to the measurement of EMG activities and ClickRT.

In order to synchronize the EMG recordings with the shot, the ticks of foot switch were overlapped with the EMG results in the same frame. The archer initiated the arrow release as a response to the stimulus from the clicker. The arrow was initially positioned between the unattached end of the clicker and the bow handle. As the arrow was pulled beyond the clicker, the clicker was released against the bow handle, which was the signal to the archer that the arrow was appropriately positioned for release. When the arrow is released, the bow experiences a high acceleration. EMG recording was made measured with a tick signal, which showed the snap of clicker.

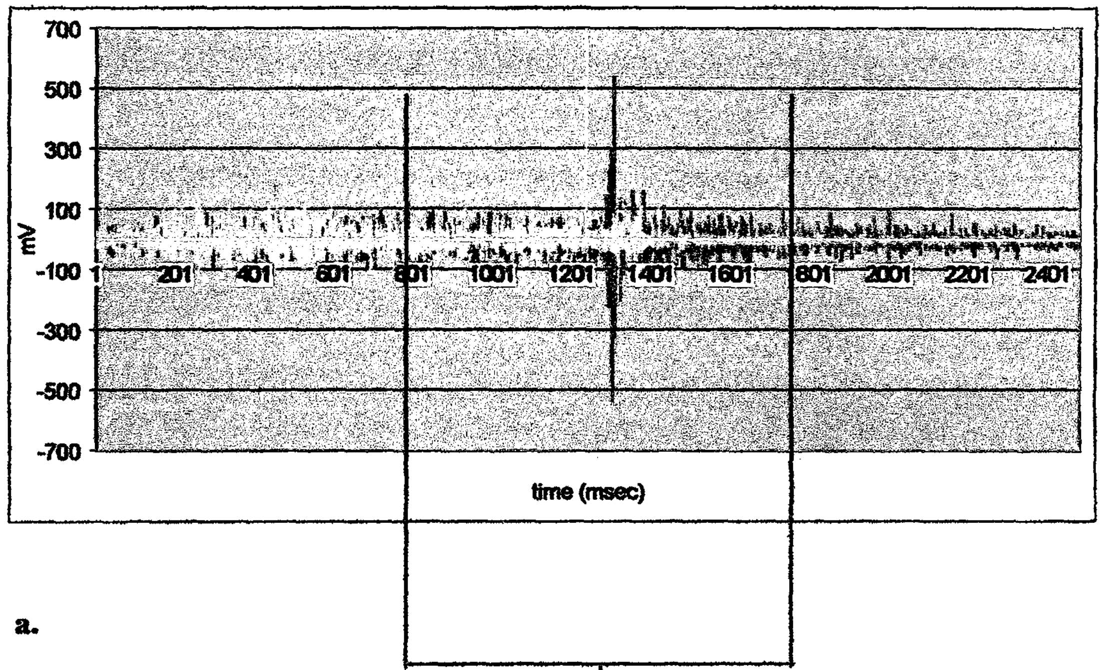
3.3.2 Data Collection Procedures for Reliability Testing

The first measurement was taken at 15 July 2000 in the Cebeci Atatürk Stadium. Each of the beginner and elite archers (totally 20 archers) shot 12 arrows from 70-m distance. The weather conditions were suitable for archery, without rain and strong wind. ClickRT, Average Speed, Flying Time, Wind Speed, Wind direction, and the Temperature scores were measured.

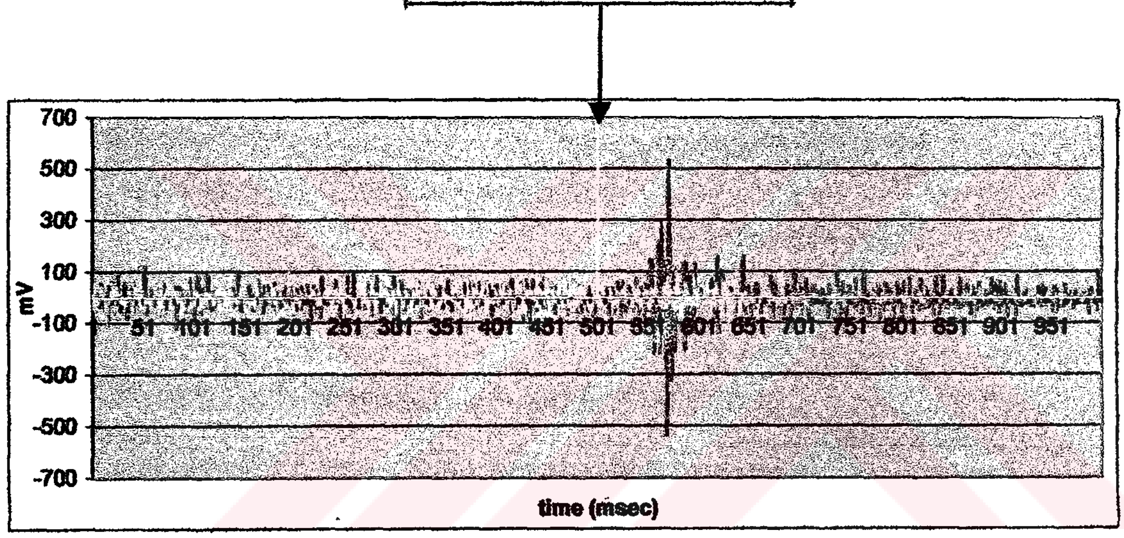
A week later (22^{nd} July 2000) all the measurements were repeated again with the same subject group, in the same shooting order, and almost in the same weather conditions. The results of the second measurement were again saved. During the reliability measurements, there were no EMG recordings.

3. 3. 3. Data Processing for Forearm Muscle Analysis

As mentioned before, EMG sampling was made in 5 – s period for a single shot in laboratory conditions. All the data, which gathered by means of OCTOPUS EMG system, was transformed to Excel package program as row data. There were Extensor Digitorum, Flexor Digitorum Superficialis muscle's activity and click signal on the same frame in the raw data of a single shot (Figure 3.6.a).



a.

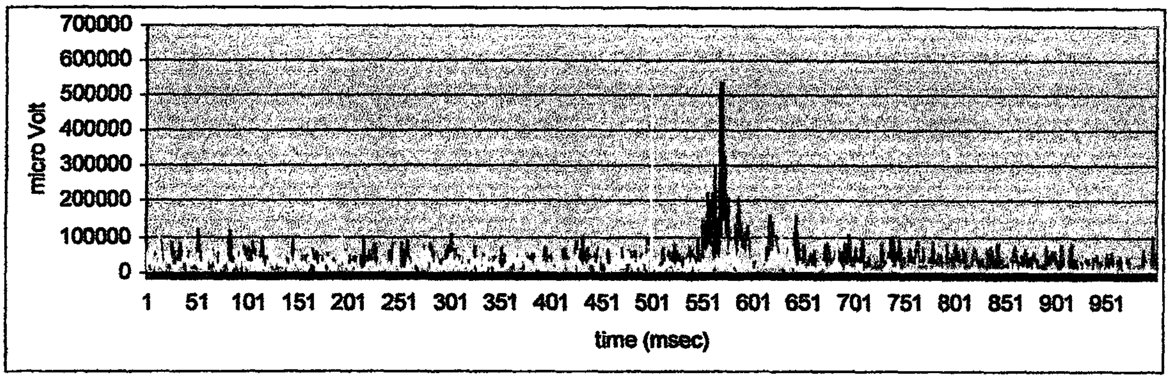


b.

☐ Extensor Digitorum ☐ Flexor Digitorum Superficialis ☐ Clicker Pulse

Figure 3.6: (a) Interference EMG recordings for 5sec period, (b) Decreased interference EMG recordings to 2 sec (one second before and one second after the clicker).

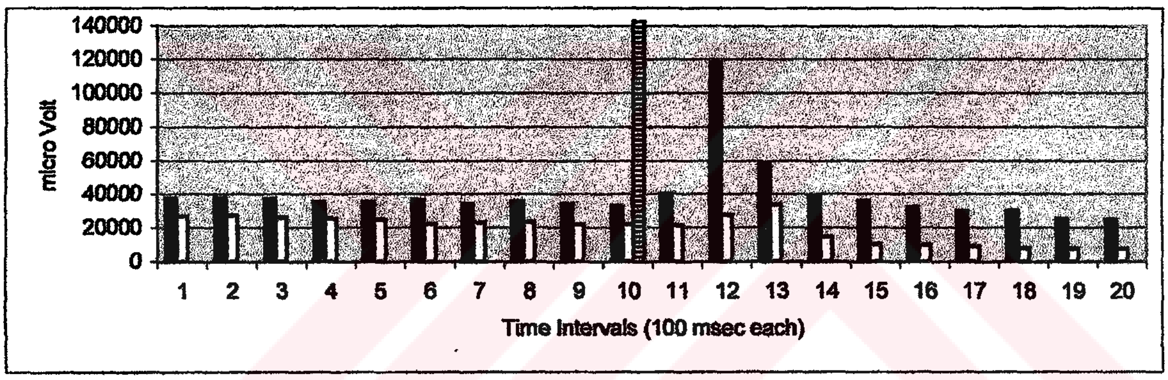
5-sec measurement period decreased to 2 sec as one-second before and after the clicker pulse (Figure 3.6.b). Then, the absolute values of 2-sec measurement were taken to get the rectified EMG results (Figure 3.7).



☐ Extensor Digitorum ☐ Flexor Digitorum Superficialis ☐ Clicker Pulse

Figure 3.7: Rectified EMG results for an archers' single shot.

The data was then averaged at each time station with 100 ms intervals, for successful shots of each subject in order to see the muscular activity of mentioned muscles during this time integrals (Figure 3.8).



■ Extensor Digitorum ☐ Flexor Digitorum Superficialis ⁝ Clicker Pulse

Figure 3.9: Integrated EMG results for an archers' single shot.

Forearm muscular analysis was made by looking at the results from the integrated EMG. First, the muscular analysis was made for each trial of each subject by reaching the integrated EMG figures. Then 12 shots were calculated in the same way. Finally all values of 100 m sec intervals were added to each other and divided into 12 to reach the average integrated score for each subject. All the above procedures were applied to all participant subjects separately.

3.3.4 Data Processing for Validity Testing

Reaction Time (Schmidt, 1991; Oxendine, 1968; Kerr, 1982; Latash, 1998) is defined as the time gap between the stimulus and the initiation of response. As we have applied this definition to the current study, we can consider the clicker signal as stimulus and the first muscular activity as the initiation of the response. From this definition the initiation of muscular activity in the forearm muscles including latent period and contraction time (Vander at. al) was considered to be the Real Reaction Time (RRT) for arrow release movement. The real reaction times were gathered from the rectified EMG results for all shots of each subject (Figure 3.9).

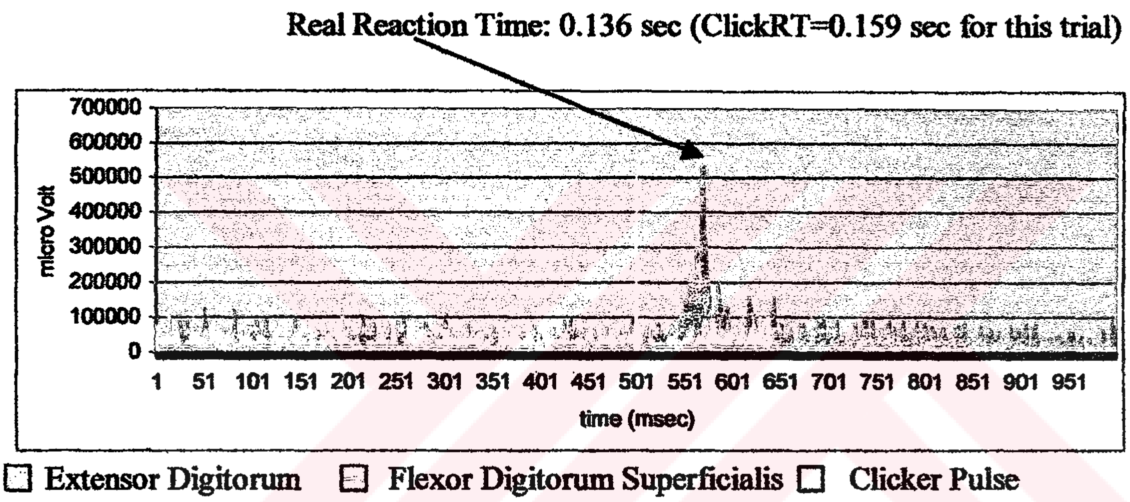


Figure 3.9: Calculation of Real Reaction Times (RRT) for each trial (In this example real reaction time was 0.136 m sec derived from excel package program manually and corresponding ClickRT was 0.159 m sec derived from ClickRT measurer).

There were two different Reaction time measurements in this study. The first one was derived from the EMG measurements and the second one from the developed Archery Chronometer. The real Reaction Time and Clicker Reaction Times (ClickRT) were correlated to test the measurement validity of developed ClickRT measurer.

CHAPTER 4

4. RESULTS

The purpose of this study is, first, to analyze the muscular activities of forearm muscles in the bow hand by means of EMG synchronized with clicker among Turkish archers and non-archers in Turkey. The second purpose of this study is to test the validity and reliability of Clicker Reaction Time Measurer (ClickRT) as a part of Archery Chronometer.

4. 1 Forearm Muscular Activities

The EMG results of Turkish Olympic Archery Team members are shown at Figure 4.1 for male and 4.2 for female subjects. All the muscular activities of the subjects were made according to integrated EMGs. 5-s interference EMGs decreased to 2-s as clicker snapped at the midpoint of measurement in all of the trials. Interference EMGs were transformed to rectified EMGs by taking the absolute values. Rectified EMGs recorded with 100 m sec intervals, before and after the click signal and during the whole shot. Averaged integrated EMGs for 12 shots of each subject were reached separately.

The results for the flexor digitorum superficialis muscle, which are presented in the same figures together with extensor digitorum muscle, were characterized by two integrated EMG profiles. Pattern 1 for the flexor digitorum superficialis muscle represents constant level of muscle activity before the click signal. The elite archers group also displayed a notable decrease in integrated EMG for 100 m sec interval immediately preceding release. The same activation pattern was observed before the clicker' snap in Pattern 2. The difference occurred between

Pattern 1 and Pattern 2 at around 200 m sec after the click signal. 6 of 10 elite archers flexor digitorum superficialis muscle activity increased again after a small decrease around 200 m sec interval.

All of the elite archers displayed the same muscular strategy for the extensor digitorum muscle except for one female archer. 9 elite archers represented a brief increase in the activation level of extensor digitorum muscle 200 m sec preceding release. There was then a modest decrease in integrated EMGs for the third interval following the click signal. One of the elite archers didn't use the extensor digitorum muscle to react the stimulus from clicker (Figure 4.2. 5a).

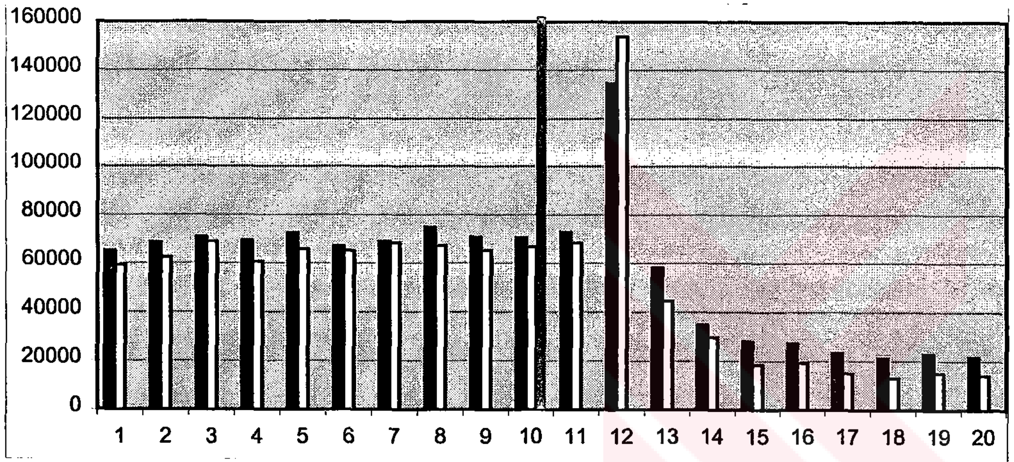
The elite archers' (Turkish Olympic Archery Team members) bow release strategies appear in general to involve simultaneous relaxation of flexor muscles and contraction of extensor muscles at around 200 ms after the clicker sound. Furthermore, a very stable co-contraction pattern of both muscle groups was noted before the clicker signal (Figures 4.1 and 4.2). On the other hand, one of the elite female archers (Figure 4.2, 5.a) showed flexor relaxation strategy meaning that when she heard the signal from clicker, she relaxed the flexor muscles without actively contracting the extensor muscle groups.

The contraction level of both muscle groups changed from subject to subject 1 second before and 1 second after the click signal and during the whole shot integrated EMG results. All of the elite archers displayed a higher contraction level in integrated EMG recordings 1 second after the click signal. It was not possible to classify for 1 second integrated EMGs before the click signal. That means each of the subjects displayed his/her own activation strategy before the click signal.

The beginner archers from Ankara Archery Club also employed the same contraction patterns with elite archers. All of the beginner archers relaxed the flexor group muscles at the same time with an active contraction of extensor group muscles. Three of the beginner female archers seemed to undergo a preparation phase involving extensor activity at around 100 ms before the clicker and therefore the co-contraction pattern of both muscle groups showed rather unstable behavior (second, fourth and fifth subject in beginner female archers).

The non-archers group also displayed unstable co-contraction pattern before the clicker. Like the elite and beginner archers group, non-archers used flexor relaxation and extensor contraction strategy after the clicker's snap. Almost all of the non-archers had a preparation phase before the clicker signal. Some of the preparation phases were caused by extreme contraction of flexor muscles and others were resulted from extensor contraction. The difference between non-archers and beginners was the values of the preparation phase. Some of non-archers reached their peak contraction values before the clicker.

ELITE MALE ARCHERS



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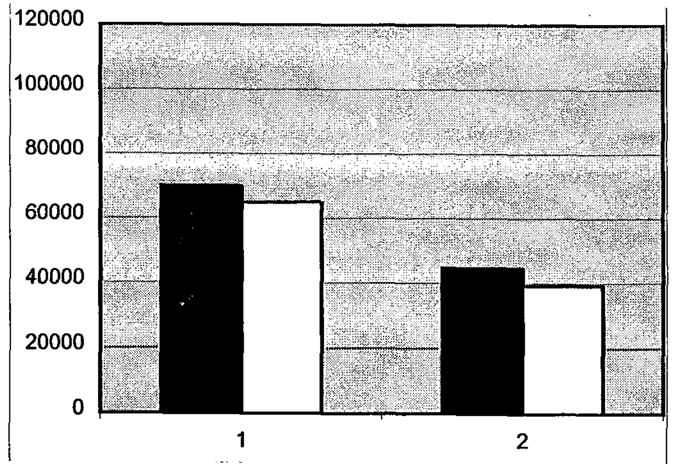

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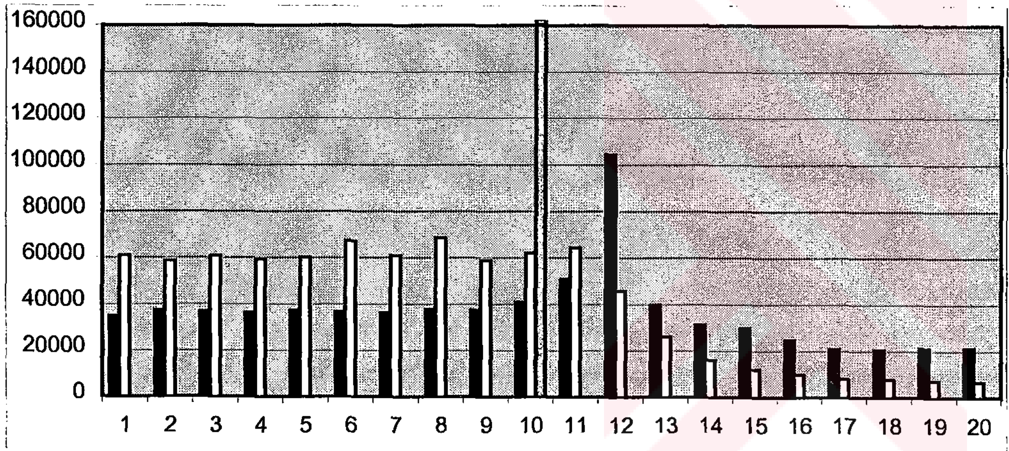

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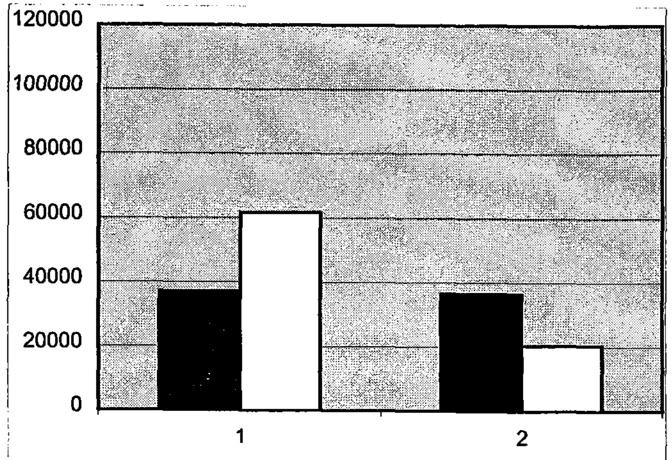

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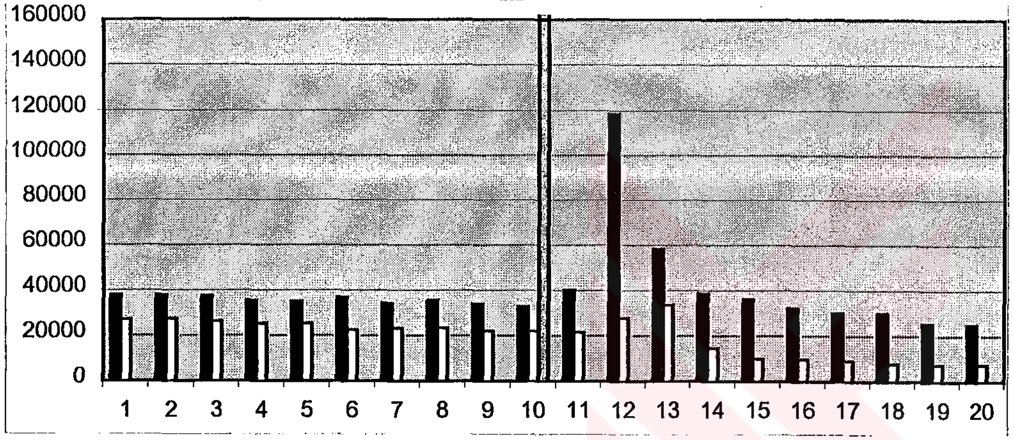
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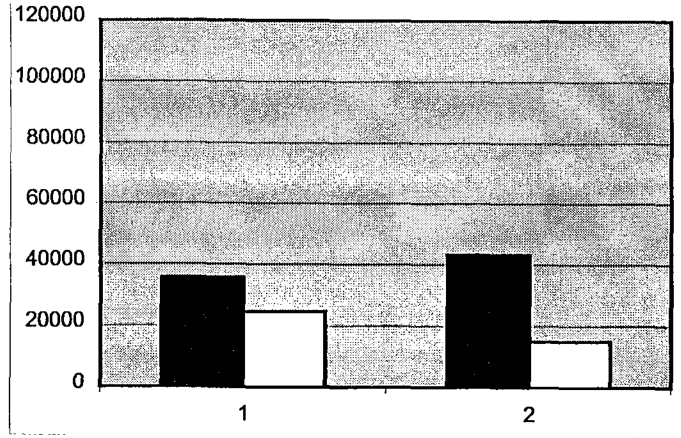
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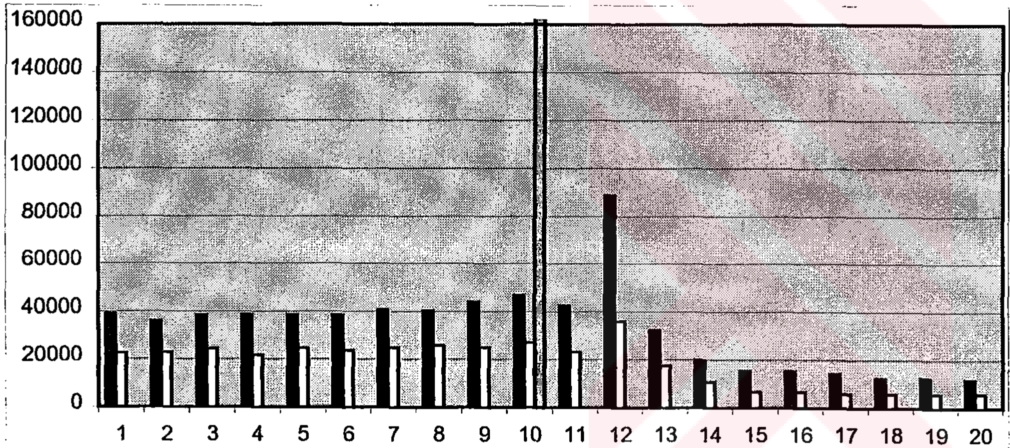
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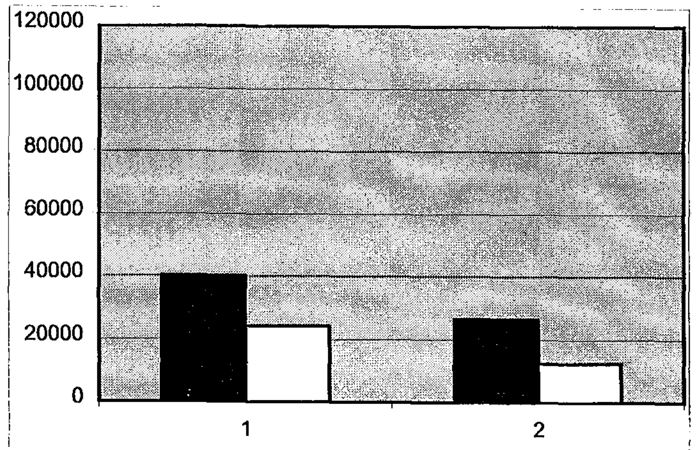
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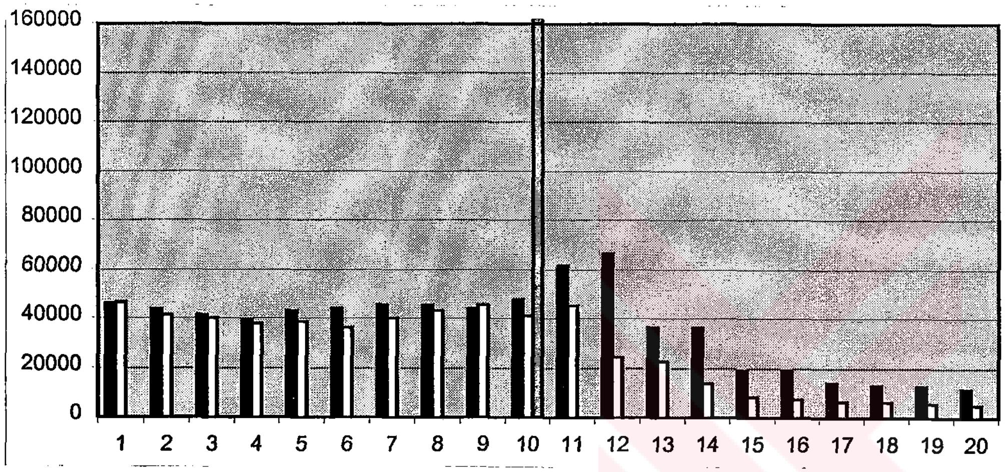

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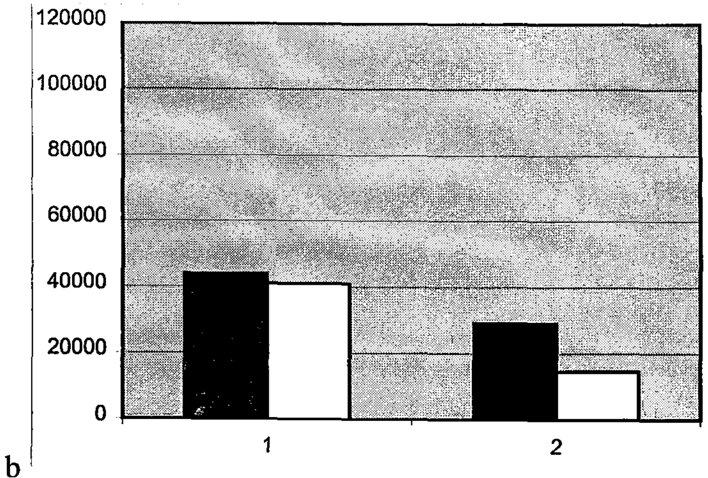

Extensor Digitorum   Flexor Digitorum Superficialis   Clicker Pulse

Figure 4.1: Integrated EMG results for 5 Elite male archers. In all the figures Y-axis denotes microvolt (μV), X-axis shows the time intervals and an archers' EMG activity in the forearm muscles gathered and averaged from successive 12 shots. The averaged EMG activities at each time station with 100 m sec intervals are displayed in the first figures for each subject separately. Second figures denote averaged EMG activities before (1) and after (2) the clicker signal.

ELITE FEMALE ARCHERS

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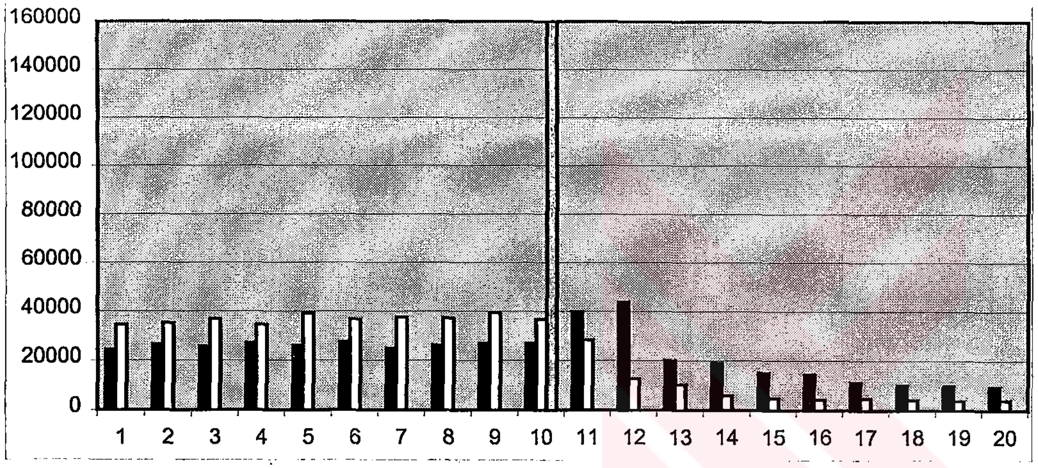

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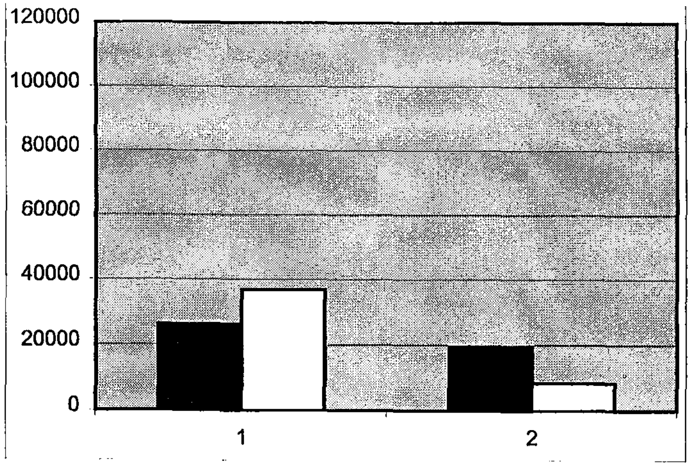

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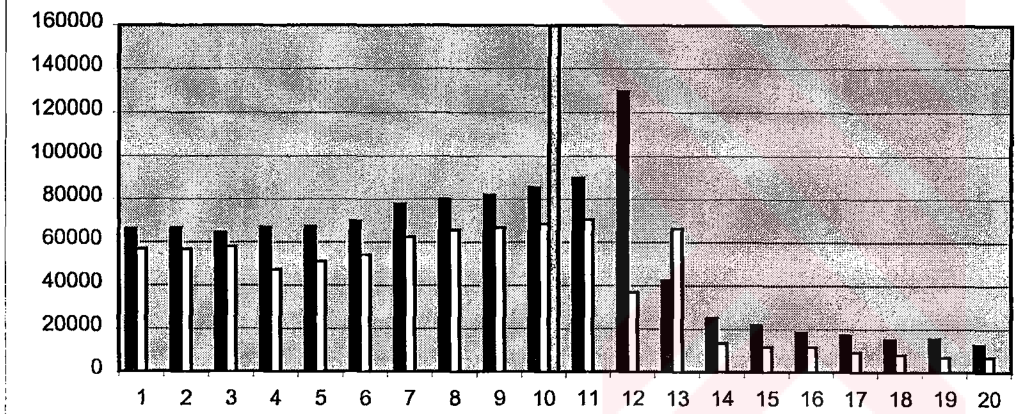

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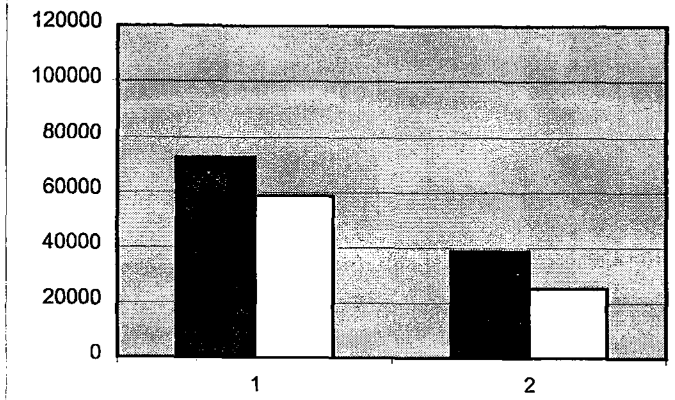

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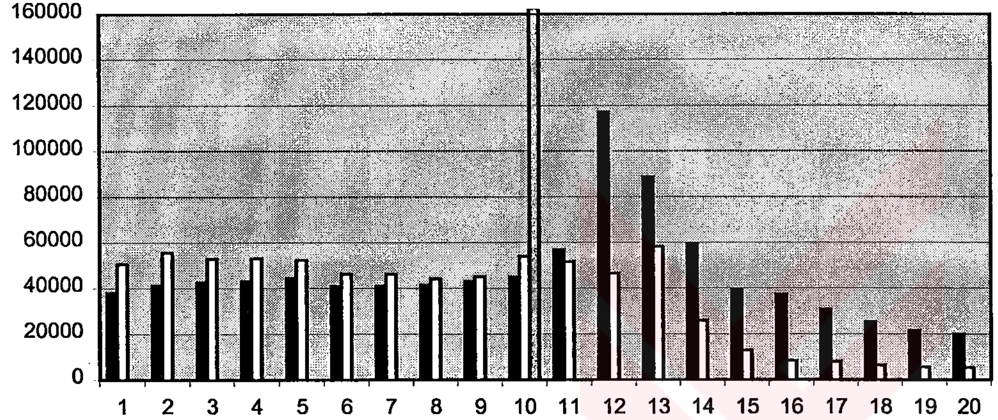
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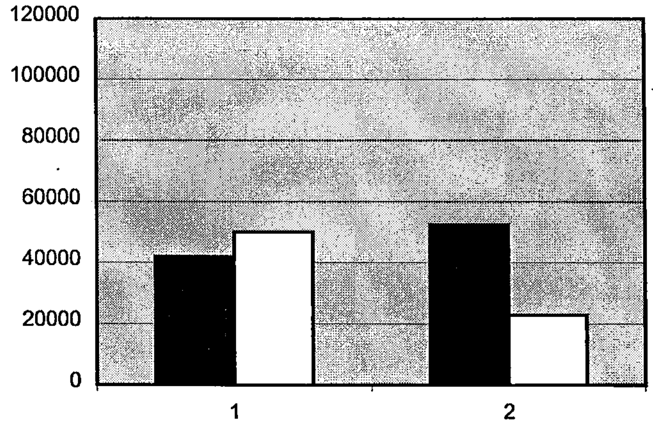
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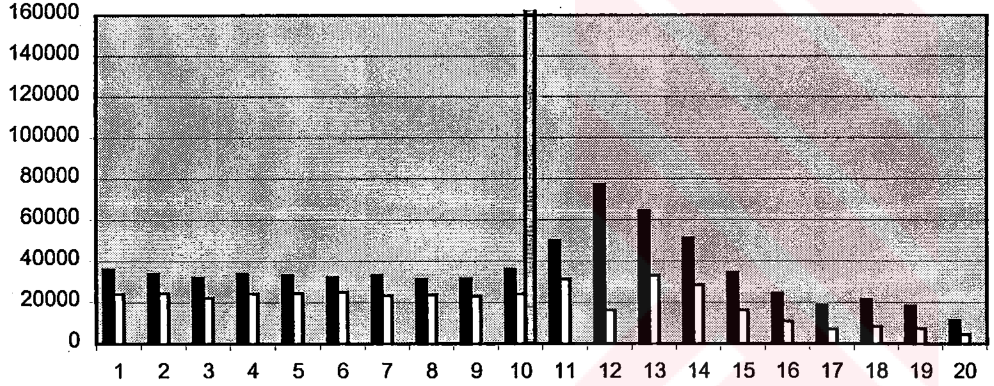
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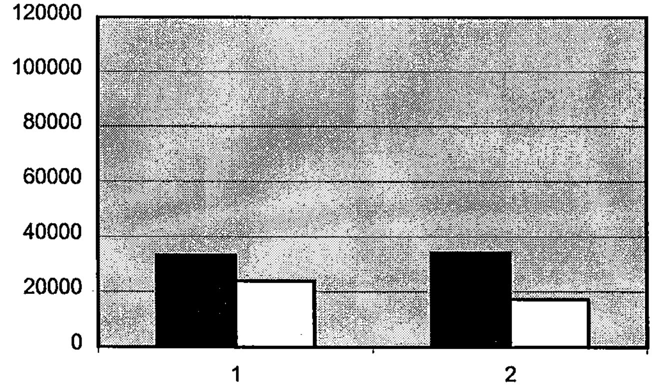
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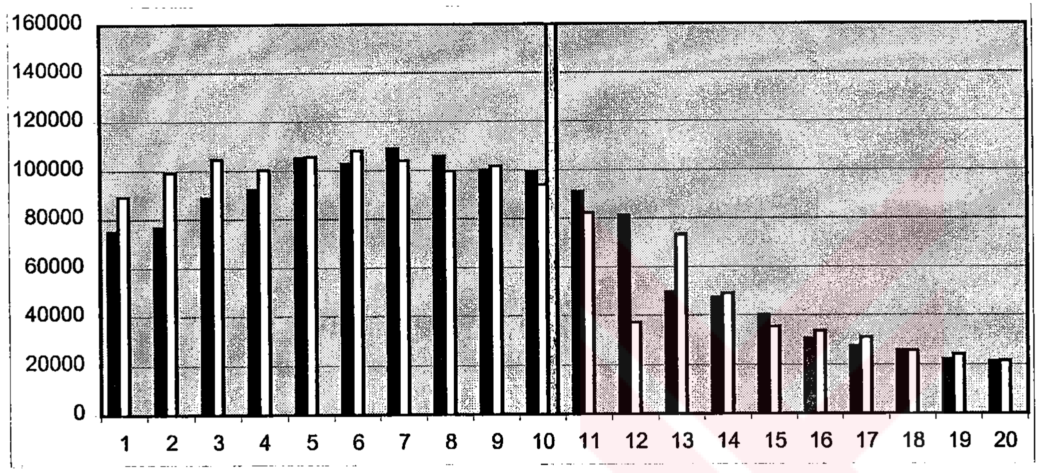

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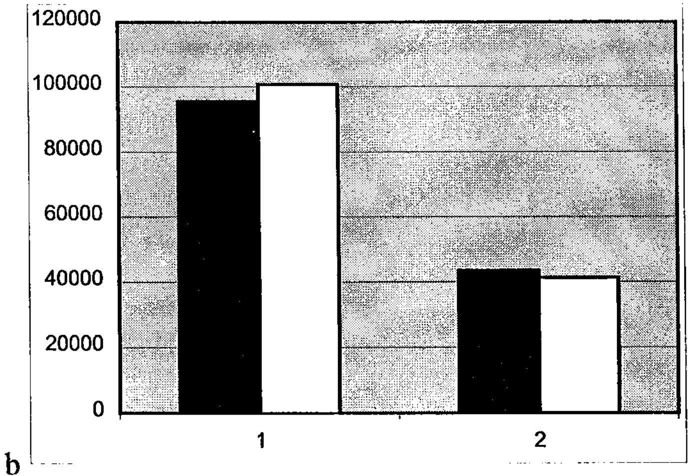
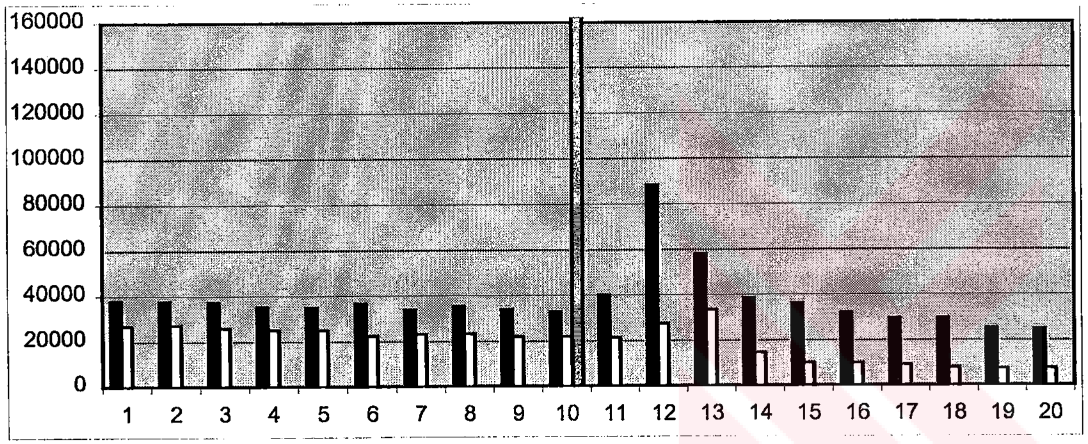


b

Extensor Digitorum Flexor Digitorum Superficialis Clicker Pulse

Figure 4.2: Integrated EMG results for 5 Elite female archers. In all the figures Y-axis denotes micro volt (μV), X-axis shows the time intervals and an archers' EMG activity in the forearm muscles gathered and averaged from successive 12 shots. The averaged EMG activities at each time station with 100 m sec intervals are displayed in the first figures (a) for each subject separately. Second figures (b) denote averaged EMG activities before (1) and after (2) the clicker signal.

BEGINNER MALE ARCHERS



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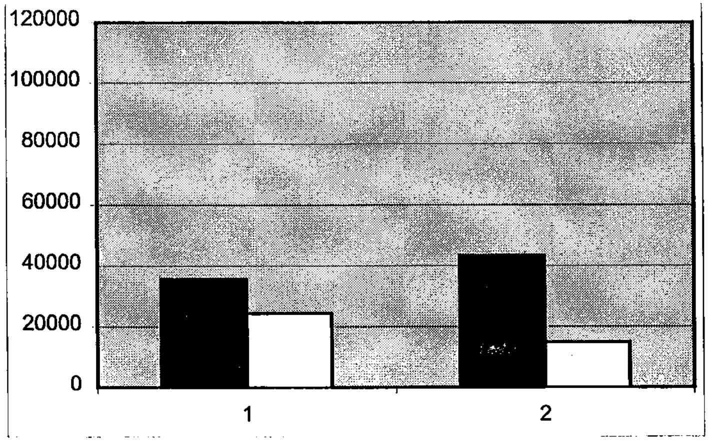

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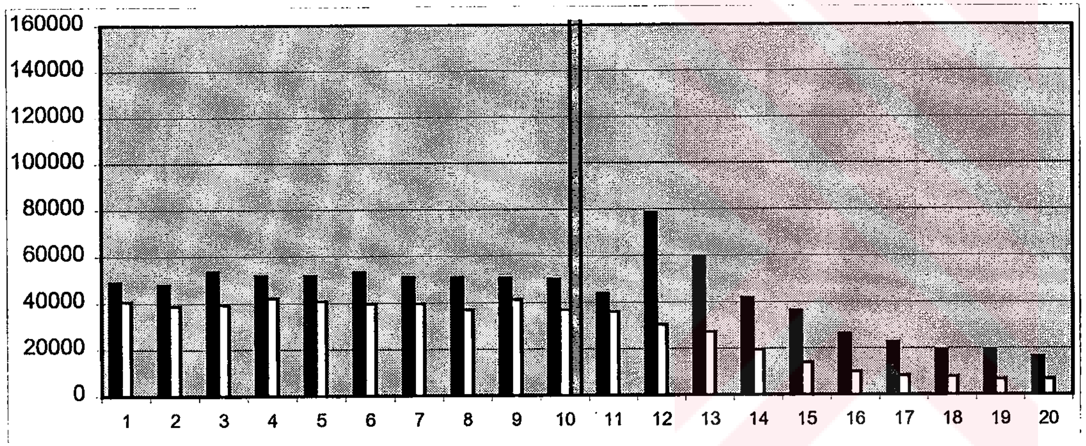

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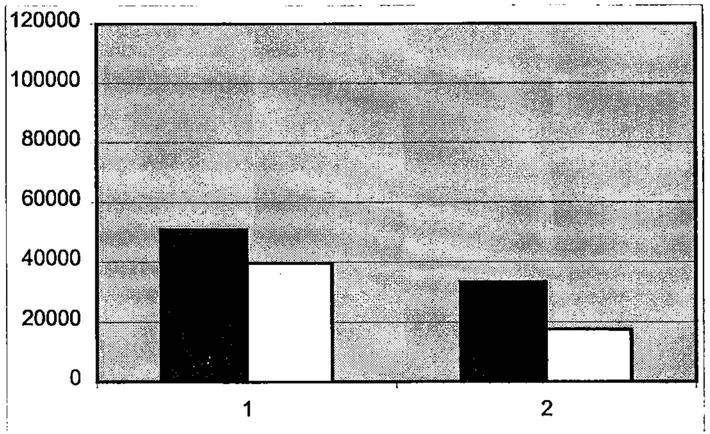

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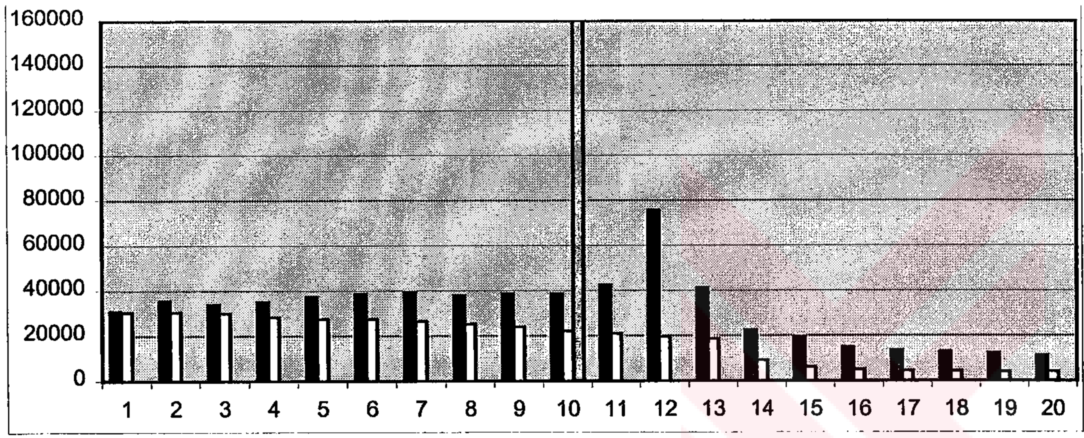
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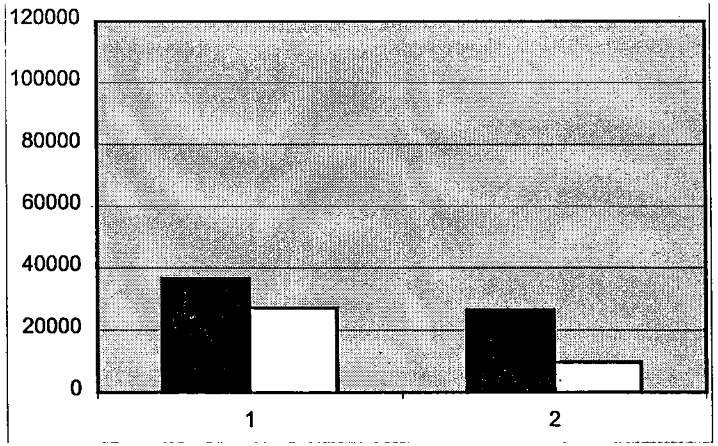
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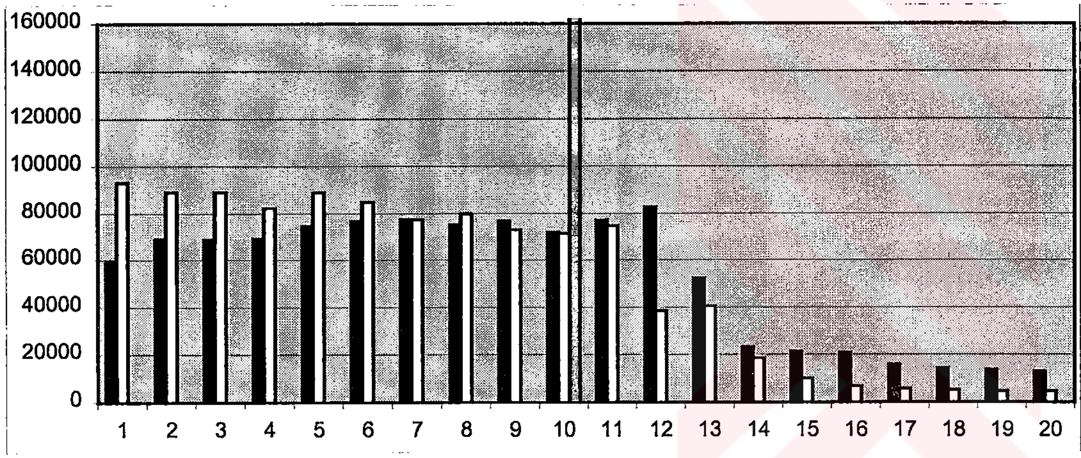
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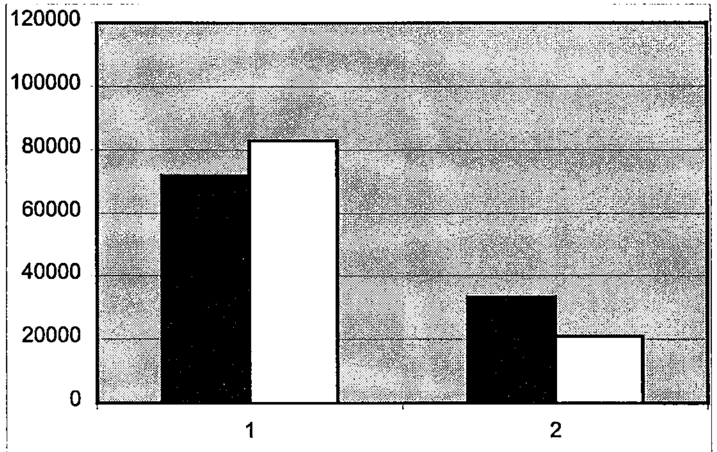
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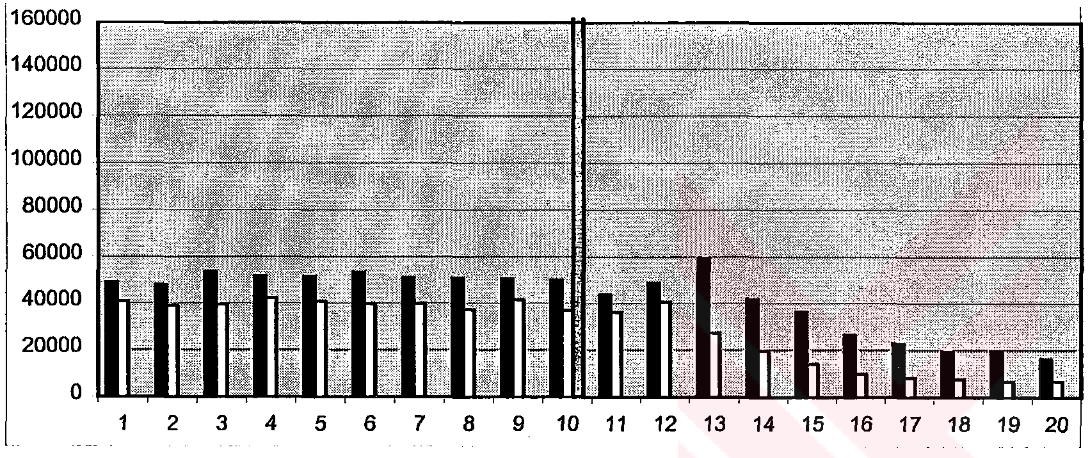

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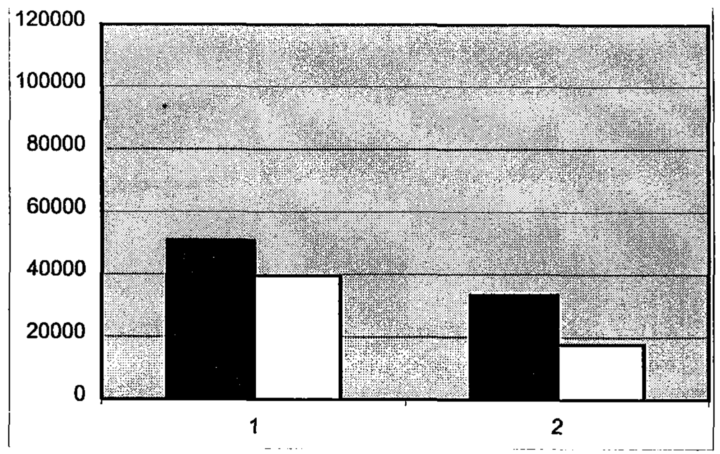
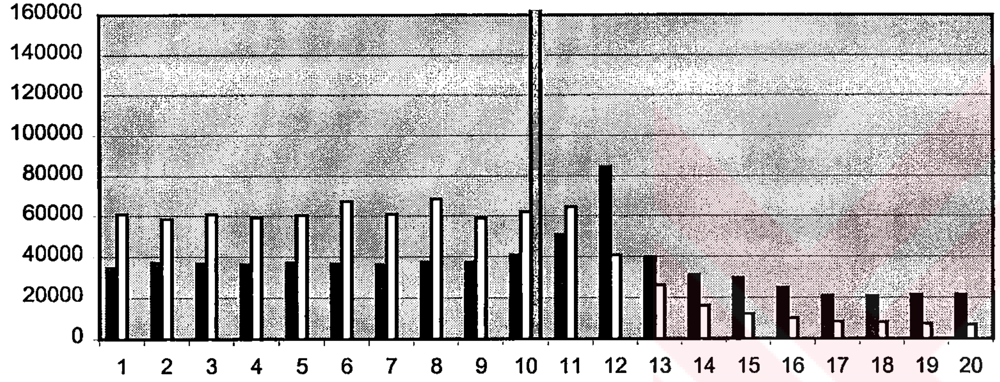


Extensor Digitorum Flexor Digitorum Superficialis Clicker Pulse

Figure 4.3: Integrated EMG results for 5 Beginner male archers. In all the figures Y-axis denotes micro volt (μV), X-axis shows the time intervals and an archers' EMG activity in the forearm muscles gathered and averaged from successive 12 shots. The averaged EMG activities at each time station with 100 m sec intervals are displayed in the first figures (a) for each subject separately. Second figures (b) denote averaged EMG activities before (1) and after (2) the clicker signal.

BEGINNER FEMALE ARCHERS



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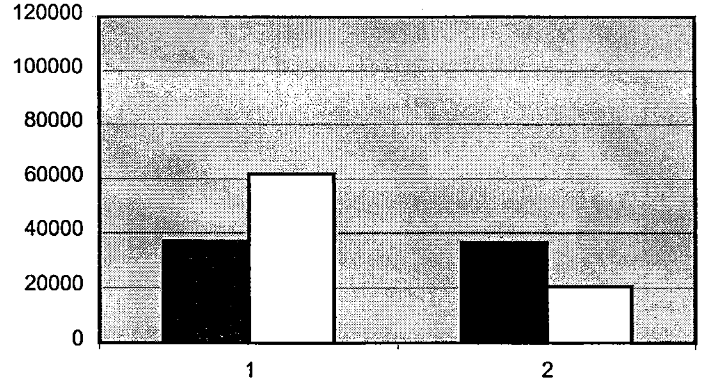

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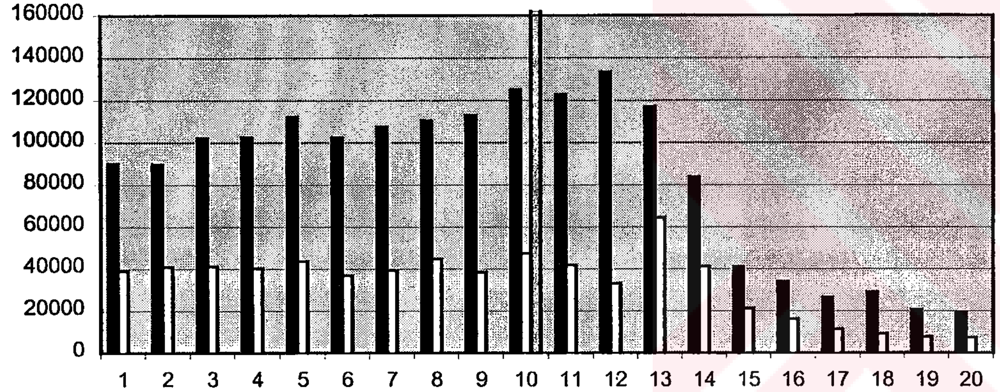

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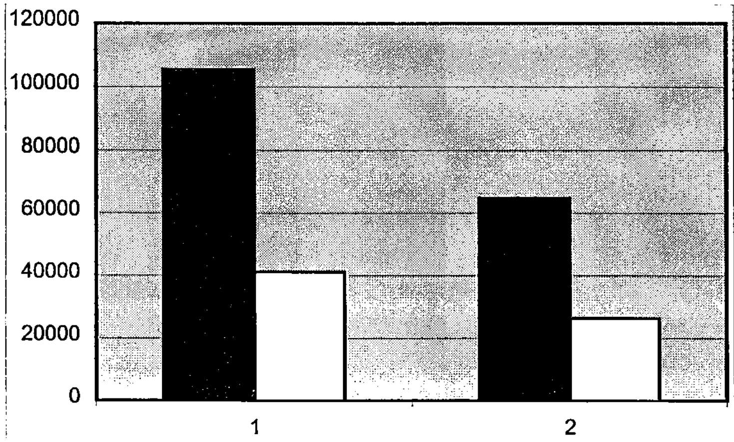

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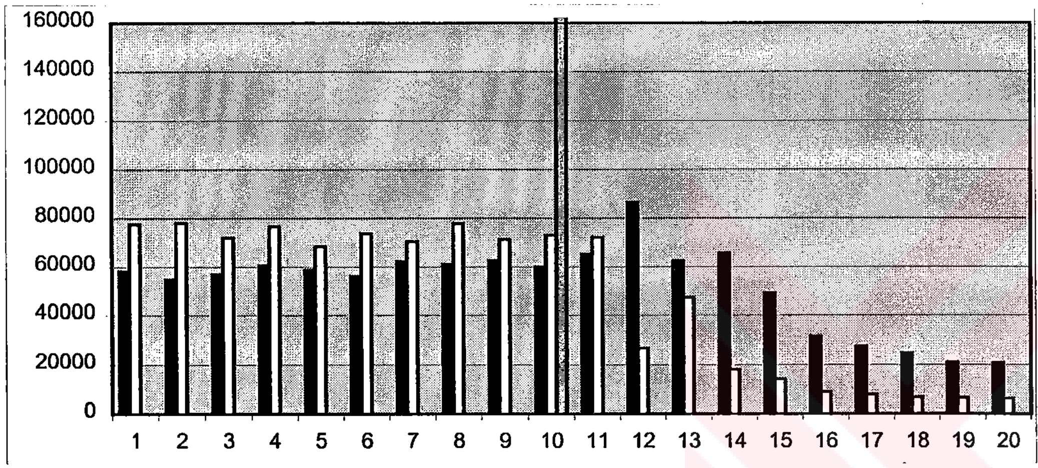

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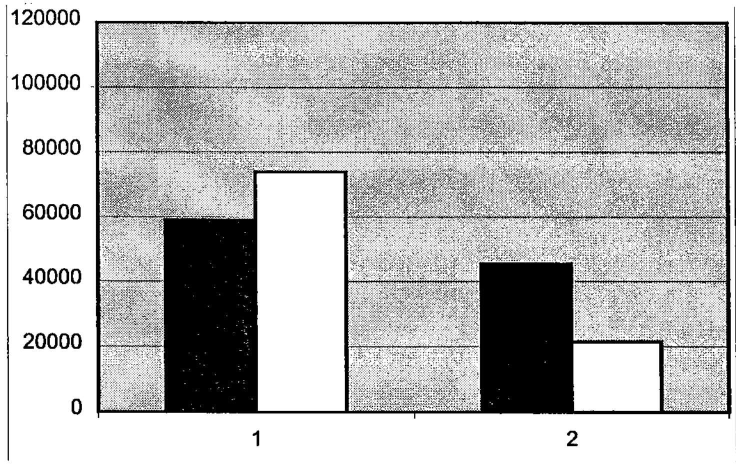

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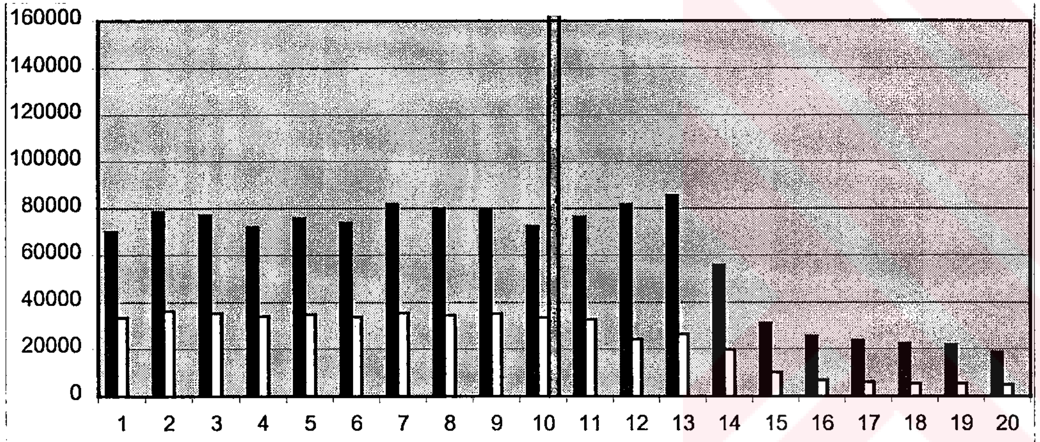

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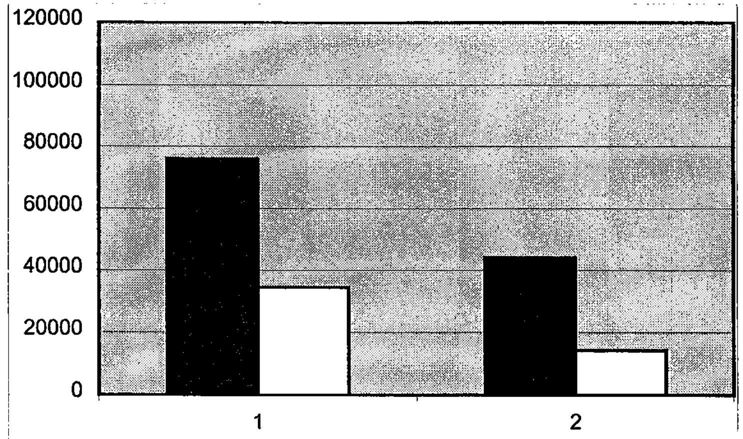

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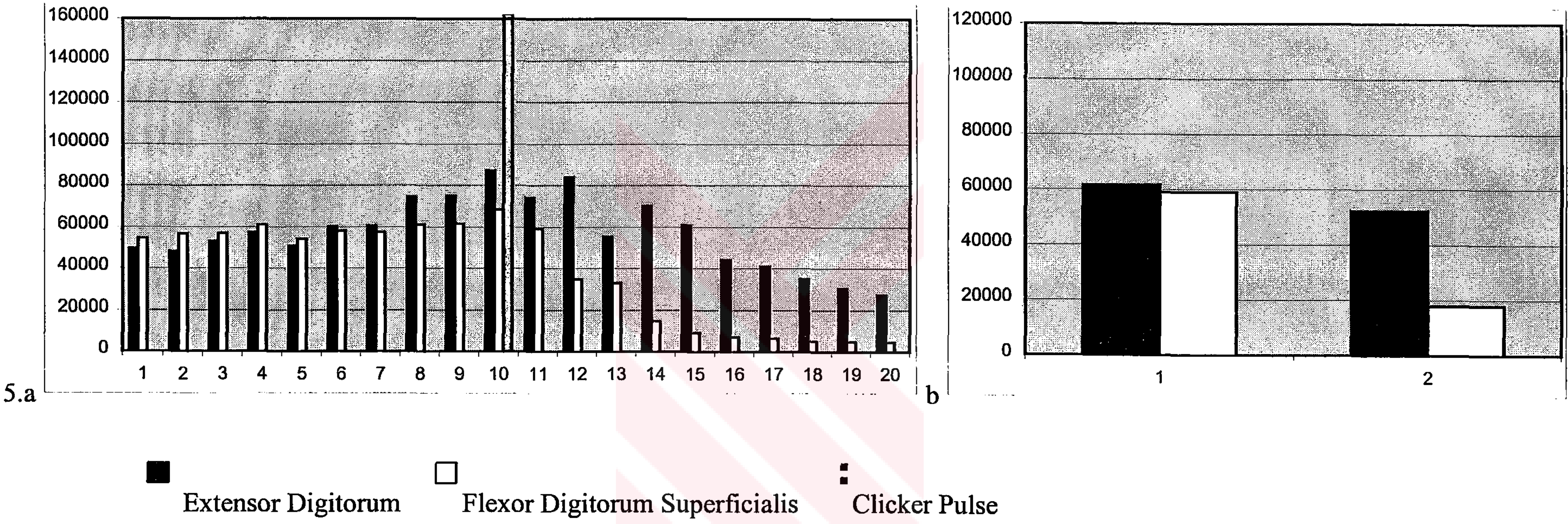
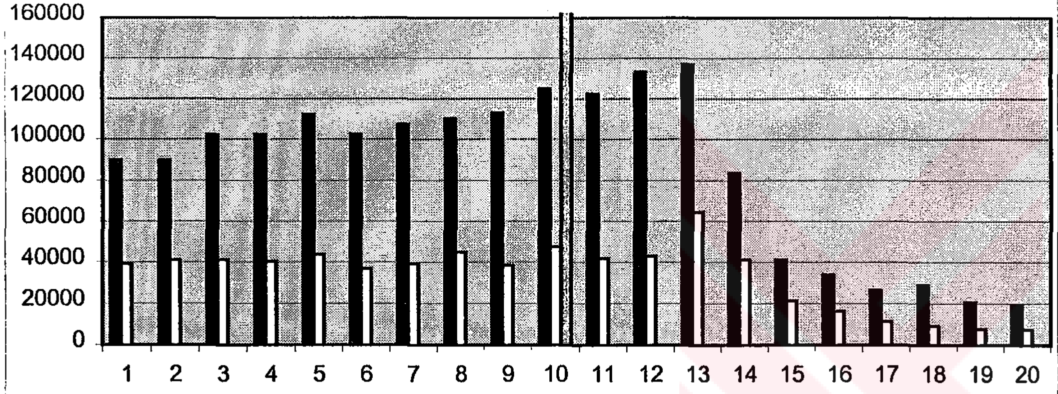


Figure 4.4: Integrated EMG results for 5 Beginner female archers. In all the figures Y-axis denotes micro volt (μV), X-axis shows the time intervals and an archers' EMG activity in the forearm muscles gathered and averaged from successive 12 shots. The averaged EMG activities at each time station with 100 m sec intervals are displayed in the first figures (a) for each subject separately. Second figures (b) denote averaged EMG activities before (1) and after (2) the clicker signal.

NON-ARCHERS MALE GROUP



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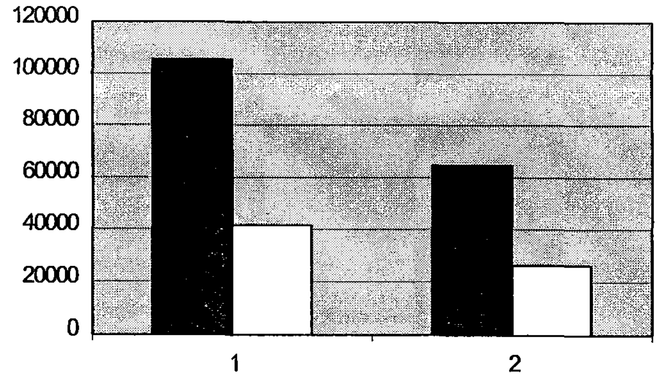

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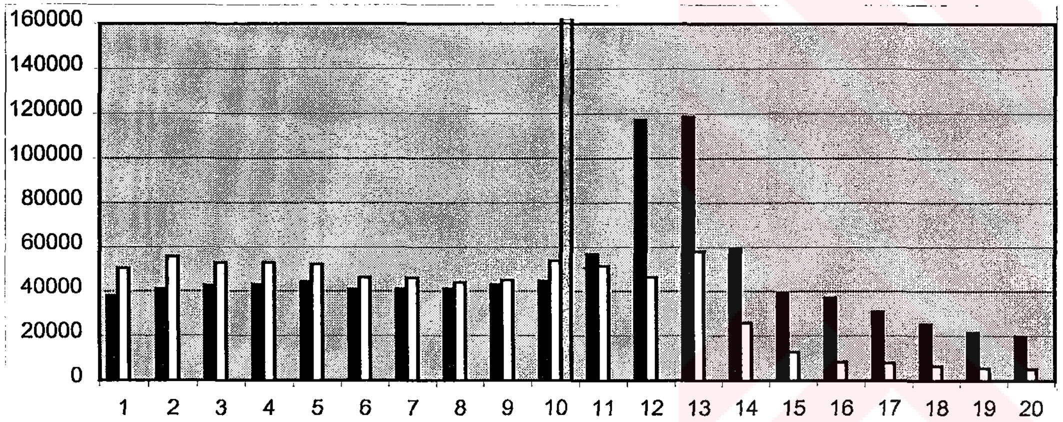

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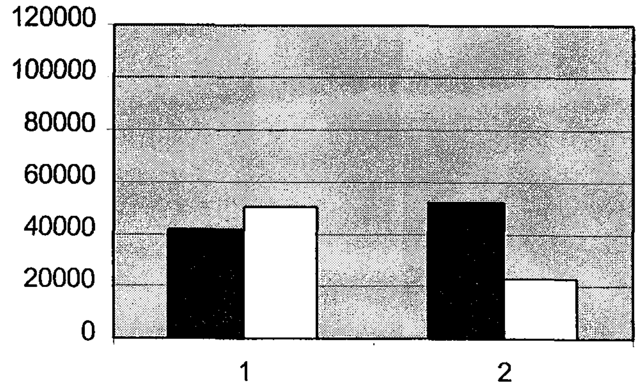

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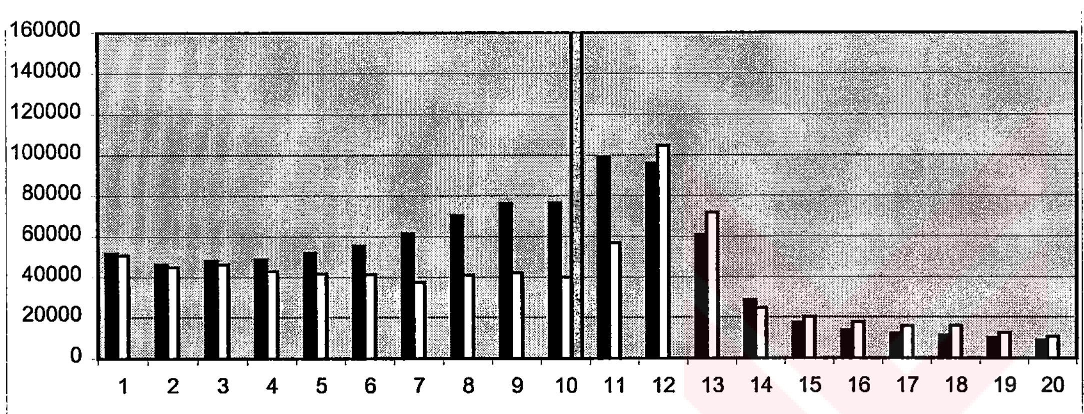
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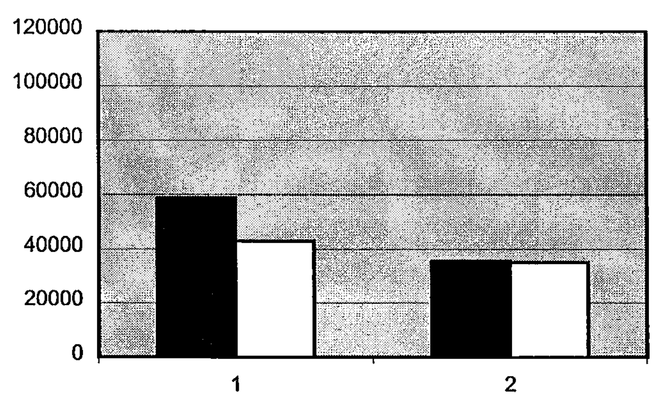
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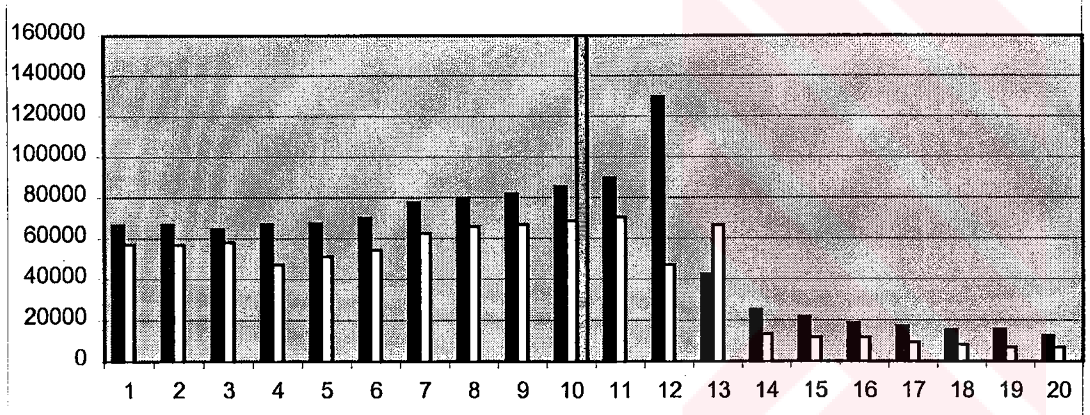
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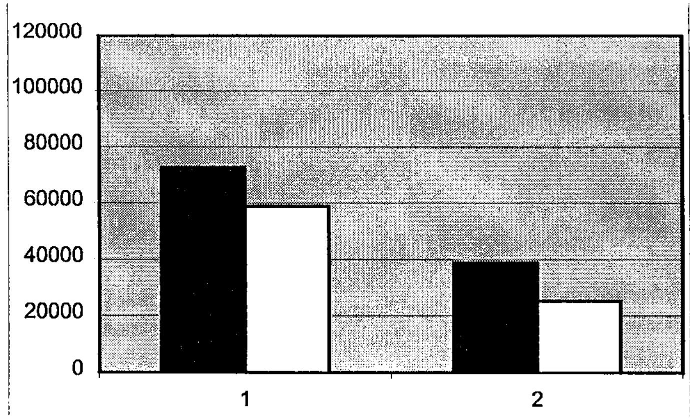
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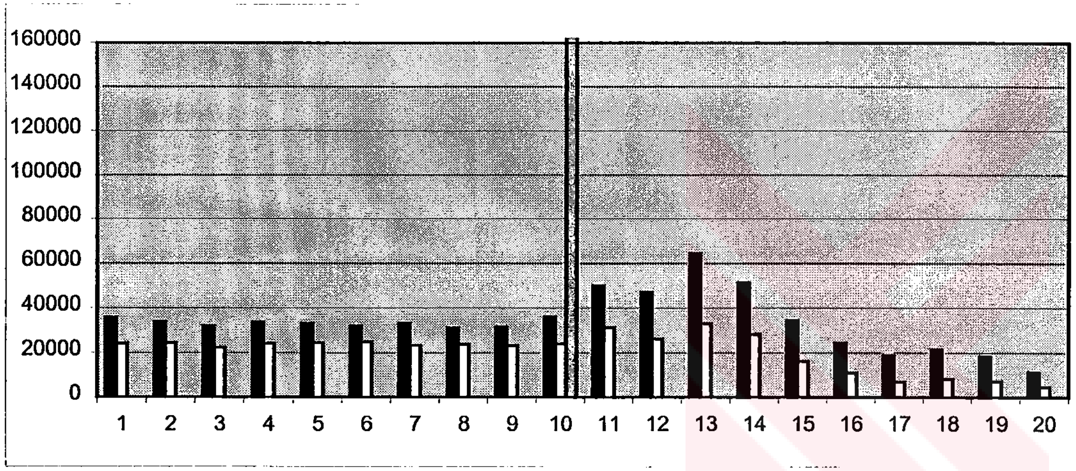

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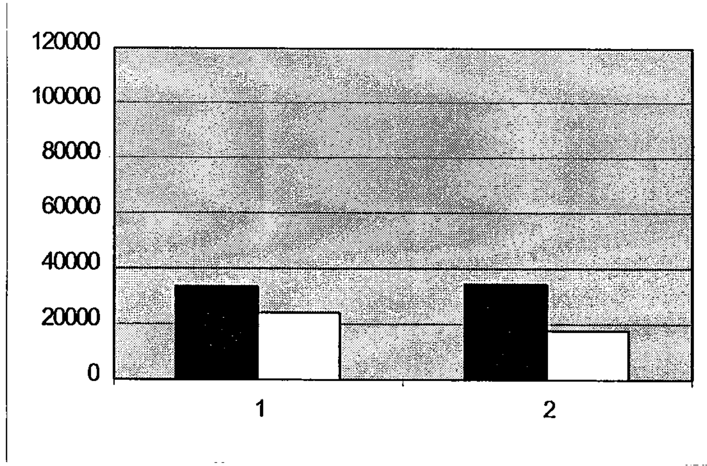
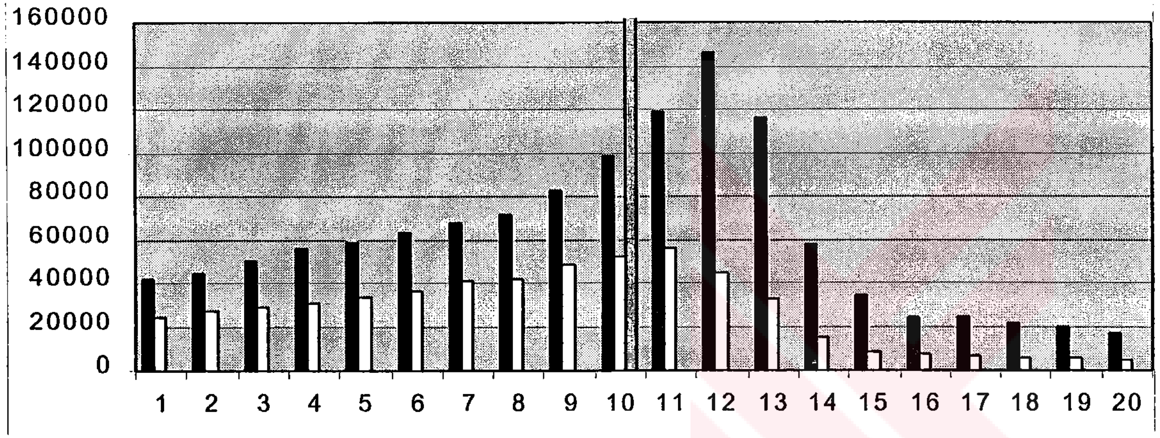


Extensor Digitorum   Flexor Digitorum Superficialis   Clicker Pulse

Figure 4.5: Integrated EMG results for 5 Non-archers male group. In all the figures Y-axis denotes micro volt (μV), X-axis shows the time intervals and an archers' EMG activity in the forearm muscles gathered and averaged from successive 12 shots. The averaged EMG activities at each time station with 100 m sec intervals are displayed in the first figures (a) for each subject separately. Second figures (b) denote averaged EMG activities before (1) and after (2) the clicker signal.

NON-ARCHERS FEMALE GROUP



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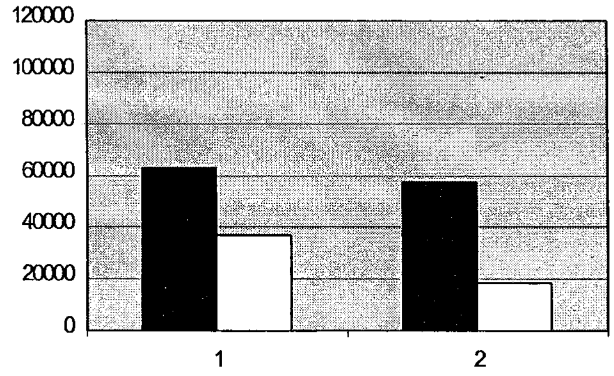

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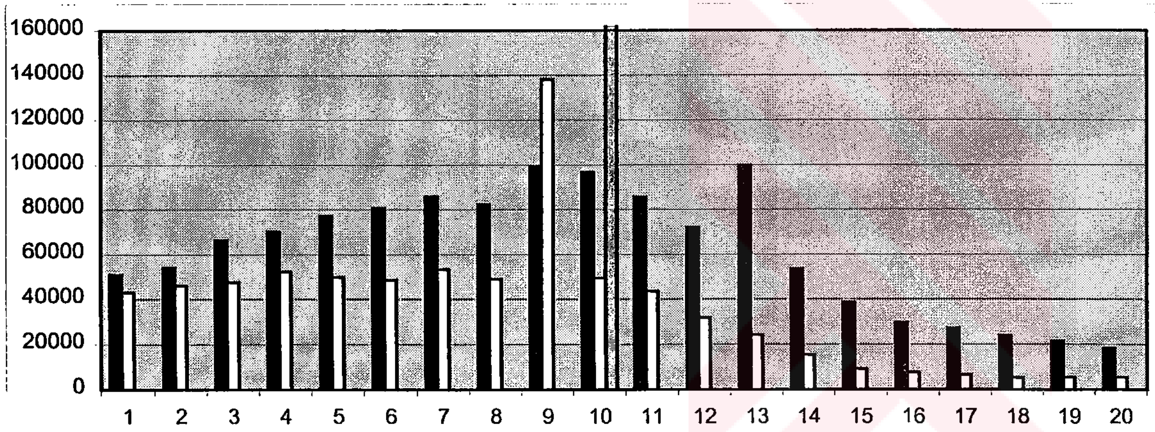

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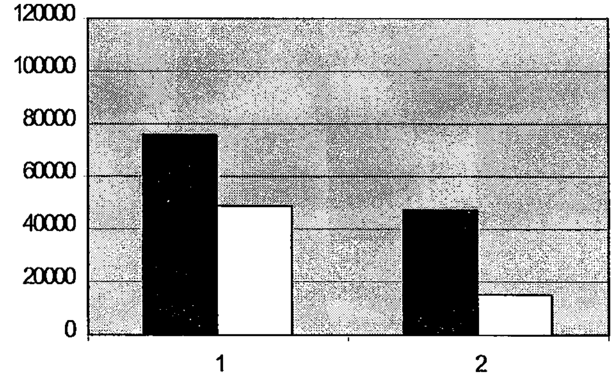

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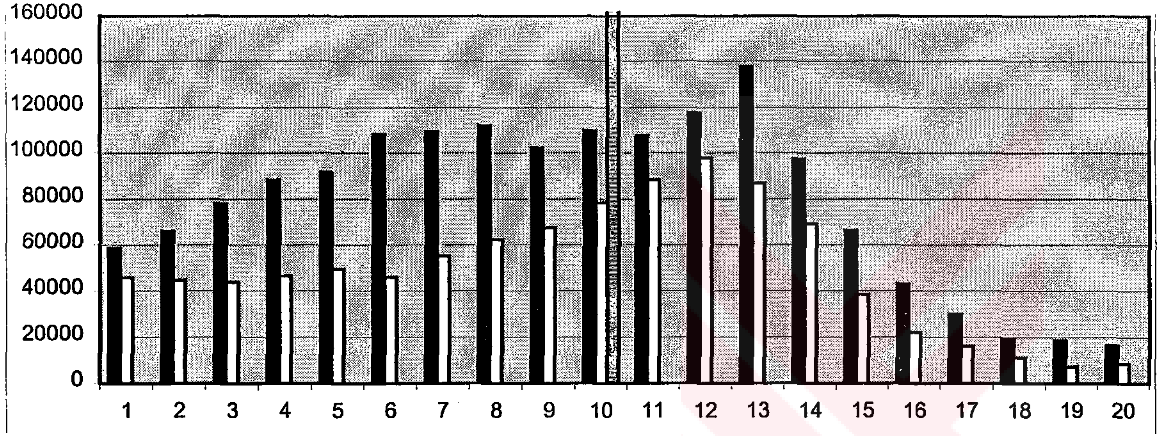
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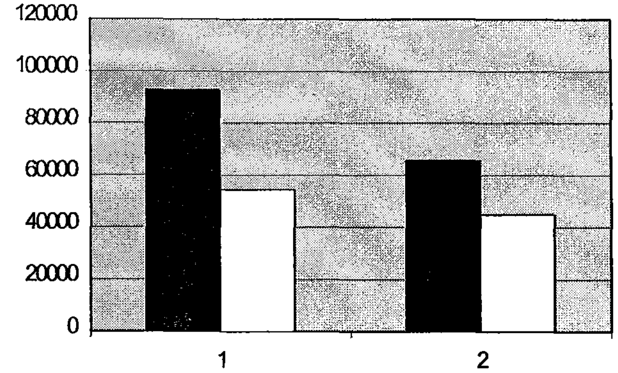
3.a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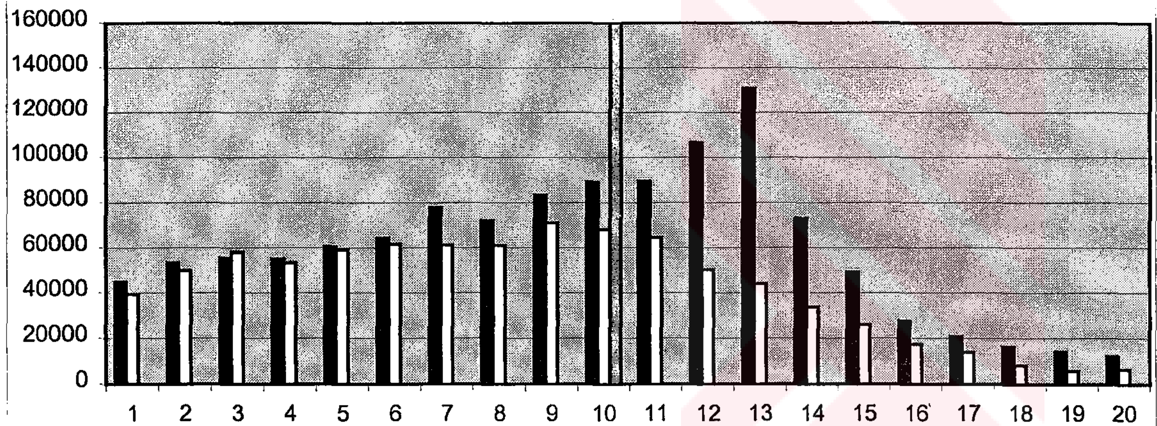
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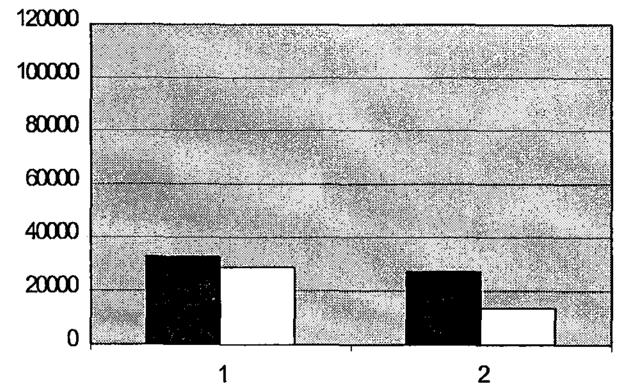
4.a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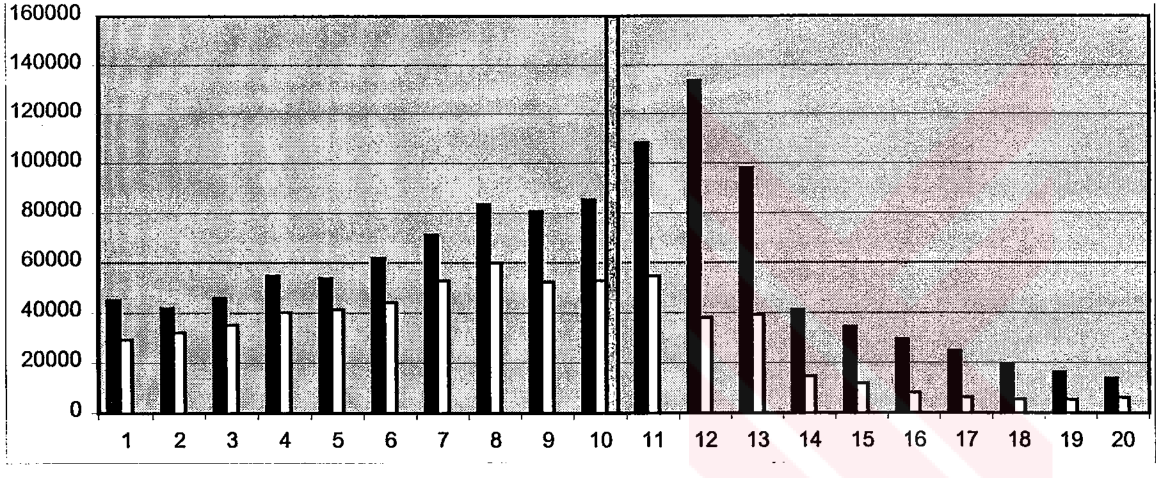
5.a



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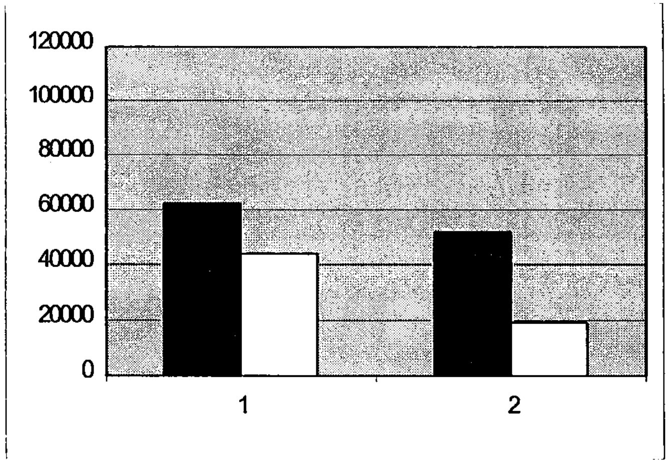
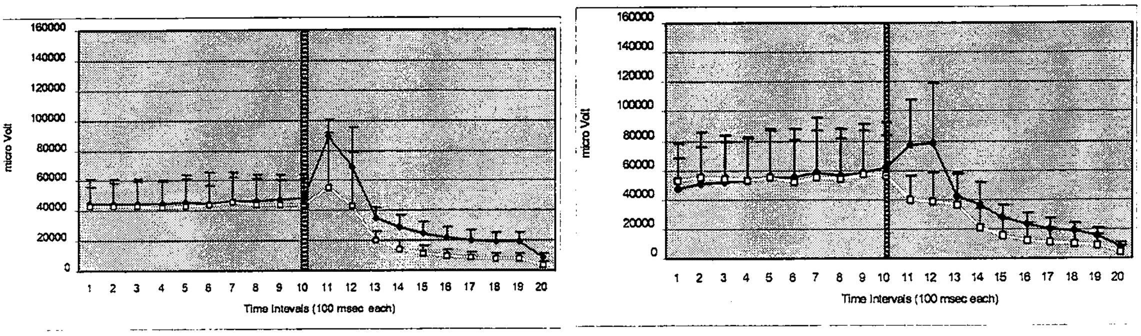


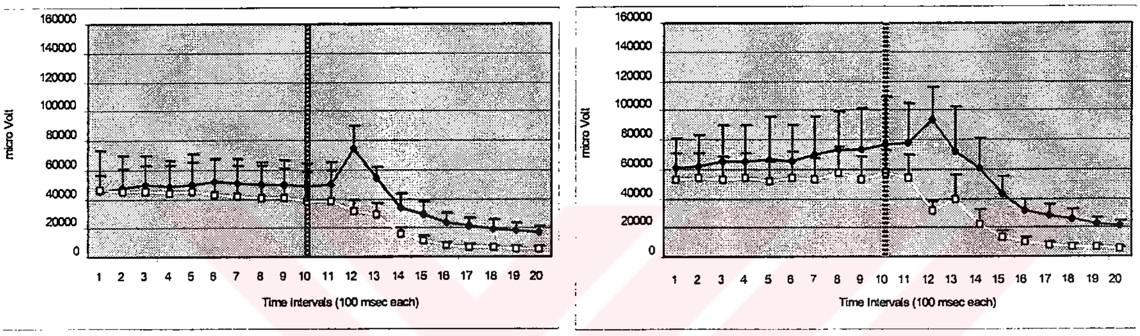
Extensor Digitorum Flexor Digitorum Superficialis Clicker Pulse

Figure 4.6: Integrated EMG results for 5 Non-archers female group. In all the figures Y-axis denotes micro volt (μV), X-axis shows the time intervals and an archers' EMG activity in the forearm muscles gathered and averaged from successive 12 shots. The averaged EMG activities at each time station with 100 m sec intervals are displayed in the first figures (a) for each subject separately. Second figures (b) denote averaged EMG activities before (1) and after (2) the clicker signal.



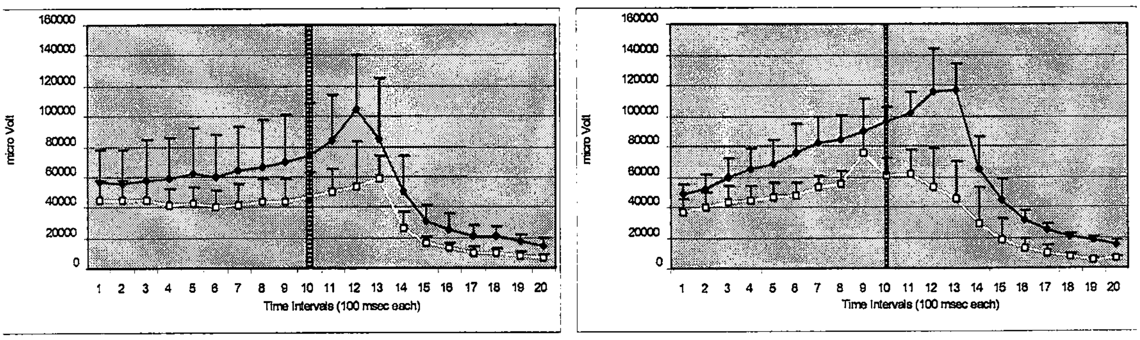
a b

Figure 4.7: Averaged and Integrated EMG results of (a) 5 elite male subjects (b) elite female subjects (Black line displays extensor digitorum, white line displays flexor digitorum superficialis muscles, and the middle column stands for clicker).



a b

Figure 4.8: Averaged and Integrated EMG results of (a) 5 beginner male subjects (b) beginner female subjects (Black line displays extensor digitorum, white line displays flexor digitorum superficialis muscles, and the middle column stands for clicker).



a b

Figure 4.9: Averaged and Integrated EMG results of (a) 5 non-archer male subjects (b) non-archer female subjects (Black line displays extensor digitorum, white line displays flexor digitorum superficialis muscles, and the middle column stands for clicker).

4.2 Validity Results of Clicker Reaction Time Measurer (ClickRT)

As mentioned before, 30 subjects from different levels were volunteered for this study. All of the subjects had two different measurements; (1) ClickRT measurement with newly developed device, (2) EMG measurements with OCTOPUS EMG Cable Telemetry System. To test the validity of ClickRT, these two measurement systems were synchronized in the same shot. Reaction Times from EMG measurement were considered to be the Real Reaction Times (Figure 3.10). EMG results of 9 out of 30 subjects were not clear enough to find out their RRT scores, meaning that, 21 subjects' EMG measurement scores were usable for evaluating their RRT scores.

Then RRT and ClickRT were correlated with each other for 252 shots totally made by 21 subjects. Mean score for ClickRT (x = 0.177 ± 5.591) was found higher than RRT (x = 0.146 ± 4.724). Beside this, ClickRT (min = 0.102, max = 0.502) minimum and maximum scores were also higher than RRT (min = 0.88, max = 0.342) (Table 4.1).

	N	Minimum	Maximum	Mean	Std. Deviation
ClickRT	252	.102	.502	.17743	5.5910E-02
RRT (by EMG)	252	.088	.342	.14622	4.7242E-02
Valid N (listwise)	252				

Table 4.1: Descriptive statistics of Clicker Reaction Times and EMG Reaction Times for 21 subjects' total 252 shots.

All of the shots were considered as a single subject that was done by 21 subjects. As like ClickRT, all of the RRT scores were written on the same column. These two columns were correlated with each other by Pearson Product Moment Correlation. The results are shown in the Table 4.2.

Null Hypothesis is rejected by this statistical analysis. There is sufficient evidience to claim that ClickRT scores are related to RRT scores in Turkish archers. That means, there is a relationship between ClickRT and RRT scores ($r = .787$, $p < 0.01$). It can be said that the ClickRT, which is measured by newly developed device is a predictor of RRT.

		EMG RT
ClickRT	Pearson Correlation Sig. (2-tailed) N	.787** .000 252

** Correlation is significant at the 0.01 level

Table 4.2: Pearson Correlation results between Clicker Reaction Times and EMG Reaction Times for 21 subjects' total 252 shots.

4.3 Reliability Results of Clicker Reaction Time Measurer (ClickRT)

The first measurement was done at 15 July 2000 in the Cebeci Atatürk Stadium for validity testing. Each of the beginners and elite archers (totally 20 archers) shot 12 arrows from 70-m distance. All of the subjects were the same with the subjects who participated in the laboratory measurements. The measurements were taken in a suitable weather condition, without rain and strong wind. Archery Chronometer measured ClickRT, Average Speed (AS), Flying Time (FT), Wind Speed (WS), Wind direction (WD), and the Temperature (TEMP) scores.

A week later (22nd July 2000) all the measurements were repeated again with the same subject group, in the same shooting order, and almost in the same weather conditions. The results of second measurement were again saved on the computer for later analysis. During the reliability measurements, there were no EMG recordings.

Descriptive statistics are given at the Table 4.3 for the first test and at the table 4.4 for the second test of Clicker Reaction Time (ClickRT), Average Speed (AS), Flying Time (FT), Wind Speed (WS), Wind Direction (WD), and Temperature (TEMP).

	N	Minimum	Maximum	Mean	Std. Deviation
ClickRT	240	.105	.327	.17953	6.7610E-02
AS (km/h)	240	160	202	189	18.342
FT (sec)	240	1.120	1.672	1.438	0.0321
WS (m/s)	240	4	8	5.856	0.0453
WD (degrees)	240	276	312	286	25.642
TEMP (Centigrad)	240	18	21	19.648	0.0243
Valid N (listwise)	240				

Table 4.3: Descriptive statistics for Clicker Reaction Time (ClickRT), Average Speed (AS), Flying Time (FT), Wind Speed (WS), Wind Direction (WD), and Temperature (TEMP) for first trial at 15 July 2000.

To test the reliability of the archery chronometer, the first and the second tests were correlated with Pearson Product Moment Correlation analysis. Null hypothesis is rejected as a result of these analyses. There is sufficient evidence to claim that Archery

Chronometer test re-test scores are highly correlated with each other at the 0.01 confidence level. That means, Archery Chronometer makes Clicker Reaction Time (ClickRT), Average Speed (AS), Flying Time (FT), Wind Speed (WS), Wind Direction (WD), and Temperature (TEMP) measurements reliably (Table 4.5).

	N	Minimum	Maximum	Mean	Std. Deviation
ClickRT	240	.102	.346	.18742	6.8220E-02
AS (km/h)	240	162	201	187	18.525
FT (sec)	240	1.112	1.596	1.392	0.0419
WS (m/s)	240	3	8	5.218	0.0512
WD (degrees)	240	279	318	289	23.582
TEMP (Centigrad)	240	19	23	21.534	0.0243
Valid N (listwise)	240				

Table 4.4: Descriptive statistics for Clicker Reaction Time (ClickRT), Average Speed (AS), Flying Time (FT), Wind Speed (WS), Wind Direction (WD), and Temperature (TEMP) for first trial at 22 July 2000.

	ClickRT (2nd Test)	AS (2nd Test)	FT (2nd Test)	WS (2nd Test)	WD (2nd Test)	TEMP (2nd Test)
ClickRT (1st Test)	0.935**	.000	.000	.000	.000	.000
AS (1st Test)	.000	0.948**	.000	.000	.000	.000
FT (1st Test)	.000	.000	0.948**	.000	.000	.000
WS (1st Test)	.000	.000	.000	0.917**	.000	.000
WD (1st Test)	.000	.000	.000	.000	0.927**	.000
TEMP (1st Test)	.000	.000	.000	.000	.000	0.976**

** Correlation is significant at the 0.01 level

Table 4.5: Pearson Product Moment Correlation analysis between first and second measurement with Archery Chronometer.

CHAPTER 5

5. DISCUSSION and RECOMMANDATION

The purpose of this study is, first, to analyze the muscular activities of forearm muscles in the bow hand by means of EMG synchronized with clicker among Turkish archers and non-archers group in Turkey. The second purpose is to test the validity and reliability of Clicker Reaction Time Measurer (ClickRT) as a part of Archery Chronometer.

5.1 Forearm Muscular Analysis

Releasing the arrow properly is the most important aspect of shooting. The key muscle force component of the release is the final one-eighth inch movement of the archer's arrow through the clicker prior to release (McKinney & McKinney, 1997). The sequences of the releasing movement by high-speed camera analysis in skilled subject are shown in Figure 2.7. From 25 m sec before release, the fingers begin extension (Nishizono, 1996). When the clicker is heard, the joints of the string fingers are ready to extend, allowing the bowstring to move forward and the arrow to release (McKinney & McKinney, 1997).

McKinney (1997) suggested that the extension of string finger joints is not the result of forceful finger extension muscle contraction by musculature in fore arm and hand. The external force for release is caused by the string as archer relaxes the tension within the finger musculature, that is, relax the "three-finger hook" around string.

On the other hand, Martin (1990) reported that both relaxation mechanism and active contraction of finger extesors were dispalyed in bowstring releasing movement by successful archers.

Arrow release movement in Turkish archers was not only caused by relaxing the flexor group muscles, but also actively contracting the extensor muscles after the clicker sound. They didn't use the bowstring as an external force for release movement.

The above observations contradict the findings of the earlier investigation carried out on elite American archers, which suggested that the finger extension is not the result of forceful muscle contruction, but the bow release is caused by the relaxation of the flexors (McKinney & McKinney, 1997). However, another investigation of the same nature reported a more active involvement of finger extensors of elite archers, in agreement with our findings (Martin et al., 1990).

Another important finding of the current study is that only 1 of 30 subjects, who is one of the most successful archers in the world, showed flexor relaxation mechanism in the arrow release movement. It should be mentioned that she immigrated from Georgia 8 years ago. When she came to Turkey, she was also one of the most successful archers in the world. This means that, learning conditions and different trainers with different teaching and training strategies can cause the variance in the muscle contraction strategy.

There were also very successful archers in the elite archers group. It is concluded that success in archery can be achieved by either of these muscle activation patterns. The small intra-individual variations in the activation patterns of the flexor and extensor digitorum muscles may not be the mechanism which distinguishes the archers of different skill levels, but rather their ability to reproduce a particular mechanism consistently from shot to shot.

Making a three-finger hook is an example of isometric finger flexion movement because the muscle groups hold a load in a constant position or attempt to move the bowstring that is greater than the tension developed by the muscle. An archer needs a high coordination level for his/her flexor or extensor muscles in the drawing arm after hearing the sound from clicker. That is why, muscular analysis can be used as an important indicator of performance level. These contractions in the agonist-antagonist forearm muscle groups are good example of excitation-relaxation coordination.

The main difference between trained archers (elite and beginner) and non-archers is the stability of muscle contraction strategy of both muscle groups before the clicker signal. The lock of coordinative abilities between arm-shoulder and forearm muscles in doing fine movements can cause differentiation in the action potential of forearm muscles. This can be one of the important signs of skill level.

The current study has not support the findings of Nishizono's (1996) study which states that, 25 m sec before the release, the fingers begin extension except for three beginner archers. This difference between these two studies can occur by not having the target face in the current study. Three of the beginner archers seem to undergo a preparation phase involving extensor activity at around 100 m sec interval before the click signal. This happens because of not knowing the correct drawing length of clicker's snap.

5.2 Validity of ClickRT Measurer

Mean score for ClickRT was 0.177 m sec with the standard deviation of 5.591, for RRT from EMG was 0.146 m sec with the standard deviation of 4.724 in 252 shots without considering the subjects separately. That means, Click RT scores are higher than RRT.

The ClickRT measurement is an indirect measurement of RRT. Archer first hears the sound from the clicker. Secondly the stimulus reaches to Central Nervous System or brain, and thirdly CNS sends the order to related muscle groups with related nerves. Then muscle starts contracting in the movement of arrow release. Finally, fingers are extended by the proper response to clicker's snap. Arrow or bowstring releases the finger and covers 1.5 cm distance. ClickRT involves all of the above stages.

Sense-organ time, brain time and muscle times are included in the RRT measurement, which is the period from the clicker signal to the beginning of the overt response. It can also be named as stimulus-to-response interval. Reaction time measurement doesn't involve movement time, which refers to the period from the beginning of the overt response to completion of a specified movement. The above definitions explain why ClickRT is longer than the RRT. As being a special response in archery, ClickRT involves both Reaction Time and Movement Time.

However, there is high correlation between ClickRT and RRT ($r = 0.787$, $p<0.01$) meaning that ClickRT can be used as an indicator or predictor of RRT in archery. It can be concluded from the statistical analysis that, ClickRT measurements are parallel with RRT measurements. ClickRT measurer can be used in predicting the RRT (r square = 0.619). R square is the measure of proportion of variability of RRT variable, which is explained by the ClickRT.

5.3 Reliability of Archery Chronometer

The results of the first and second measurements are given in the tables 4.3 and 4.4. Six kind of measurements taken by Archery Chronometer were correlated by using Pearson Product Moment Correlation coefficient. High correlations are found between test re-test scores at the significance level of 0.01. Archery Chronometer gives the same measurement results in different times, which means that newly developed device can be used safely in measuring Clicker Reaction Time (ClickRT), Average Speed (AS), Flying Time (FT), Wind Speed (WS), Wind Direction (WD), and Temperature (TEMP).

5.4 Recommendations

1. Muscular analysis should involve arm and shoulder muscles in evaluating the muscular strategy in archery.
2. A comparison can be made between different teaching techniques or different nations' archery teams. This kind of evaluation will be helpful in evaluating the personal differences.
3. The subject can be asked to sight a special point on target face to search for the sighting effect on muscular activity.

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