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NADJILA TEJO MACHADO

Temporal pattern in the muscles of the upper limbs and the trunk in the archery

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Board of Examiners

Prof. Dr. Fernando Henrique Mahalhães

University of São Paulo. College of Arts, Sciences and Humanities

Prof. Dr. Alberto Carlos Amadio

University of São Paulo. School of Physical Education and Sport

Prof. Dr. Paulo Barbosa de Freitas Junior

Universidade Cruzeiro do Sul

I dedicate to all who contributed to my journey...

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"To use a metaphor, we might say that the organism is constantly playing a game with its environment, a game where the rules are not defined and the moves planned by the opponent are not know. It is this peculiarity of real relationships – the evaluation of situation by the organism is probably no less sensitive than its choice of action – that distinguishes the living organism from a reactive machine no matter how sensitive and complex the latter may be. Reactive mechanisms play an important role as technical components in the adjustable regulation of action, but never as direct determinants of action and behaviour"

(BERNSTEIN, 1967, p. 173)

ABSTRACT

MACHADO, Nadjila Tejo. **Temporal pattern in the muscles of the upper limbs and the trunk in the archery**. 2018. 140 p. Dissertation (Master Degree in Sciences) – College of Arts, Sciences and Humanities, University of São Paulo, São Paulo, 2018. Corrected Version.

Central nervous system stabilizes body in disturbance by means of anticipatory and compensatory postural adjustments to maintain stable position. Disturbance effects in joint are reduced by activation of agonist and antagonist forearm muscles, the muscles allow consistency by steady posture during shot. Studies showed the importance of posture in the shot, but without focus on the anticipatory and compensatory postural adjustments. The objective of this study was to analyze an electrical activity of archers during the shot an arrow with the bow. Participants consisted of 10 archers of the Brazilian National Team of archery. Electromyography captured electrical activity in 12 muscles. Accelerometer in handle indicated the beginning of the movement. Temporal pattern separated in 500 milliseconds pre and post clicker fall. Protocol started by Maximal Voluntary Isometric Contraction of 12 muscles. Archers release 3 blocks of 6-arrows in warm-up. Archers throw arrows for 12 blocks with 6-arrows with interval of 20 minutes after the block 6. One-way Analysis of Variance and Tukey Test compared temporal pattern. One-way Analysis of Variance with repeated measures compared temporal pattern and 6-arrows. Results showed that all muscles (except m. Lumbar Multifidus) increase in their demand with the proximity of the arrow release. The muscles decreased their activity due to reduced demand in compensatory and modulation phase. Comparison between 12 blocks of 6-arrows showed 3 ways of temporal pattern: 1) muscles affected by phases and muscles affected by all/any phases in the blocks of 6-arrows, 2) muscles affected by phases and muscles unaffected by all/any phases in the blocks of 6-arrows and 3) muscles unaffected by phases and muscles affected by all phases in the blocks of 6-arrows. Muscles were not affected by phases/blocks maintain muscle activity along intervals by similar muscular demand. Cross-correlation between motor muscles showed that forearm muscles obtained inverse relationship between them. Other motor muscles were strong correlation between them. Postural muscles m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius were strong correlation with all postural muscles. Motor and postural muscles showed that m. Triceps Brachii, m. Pectoralis Major Clavicular Head and m. Posterior Deltoid showed strong correlation with all postural muscles. In conclusion, muscle activity increases in anticipatory phase and muscle activity decrease after clicker fall. There are 3 ways to compare phases and blocks: affected by phases and 1) muscles affected/2) muscles unaffected by all/any phases in the blocks of 6-arrows and 3) muscles unaffected by phases and affected by all phase in the blocks of 6-arrows. Correlation in motor muscles showed that forearm muscles obtained inverse relationship between them. Postural muscles m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius were strong correlation with all postural muscles. Motor and postural muscles showed that m. Triceps Brachii, m. Pectoralis Major Clavicular Head and m. Posterior Deltoid showed strong correlation with all postural muscles.

Keywords: Archery. Biomechanics. Electromyography. Muscle activity. Motor control.

RESUMO

Machado, Nadjila Tejo. **Padrão Temporal nos Músculos dos Membros Superiores e do Tronco no Tiro com Arco**. 2018. 140 f. Dissertação (Mestrado em Ciências) – Escola de Artes, Ciências e Humanidades, Universidade de São Paulo, São Paulo, 2018. Versão Corrigida.

O sistema nervoso central estabiliza o corpo na perturbação por meio de ajustes posturais antecipatórios e compensatórios para manter a postura estável. Os efeitos da perturbação na articulação são reduzidos pela ativação dos músculos agonistas e antagonistas do antebraço, os músculos permitem a consistência no tiro pela postura estável. Os estudos mostram a importância da postura no tiro, mas não se concentrarem nos ajustes posturais antecipatórios e compensatórios. O objetivo desse estudo foi analisar a atividade elétrica muscular de arqueiros durante o atirar uma flecha com o arco. Os participantes foram 10 arqueiros da Seleção Brasileira de Tiro com Arco. A eletromiografia captou a atividade elétrica muscular de 12 músculos. O acelerômetro no punho indicou o início do movimento. As fases temporais foram separadas entre 500 milissegundos pré e pós queda do clicker. O protocolo iniciou pela Contração Isométrica Voluntária Máxima dos músculos. Arqueiros lançaram 3 séries de 6 flechas no aquecimento. Arqueiros lançaram 12 séries de 6 flechas com intervalo de 20 minutos após a série 6. Análise de Variância One-way e o Tukey compararam as fases temporais. Análise de Variância One-way com medida repetidas comparou as fases temporais e os blocos de 6 flechas. Os resultados mostraram que todos os músculos (exceção do m. Multifido Lombar) aumentaram a demanda com a proximidade de soltura da flecha. Os músculos diminuem sua atividade pela redução da sua demanda na fase compensatória e de modulação. A comparação entre blocos de 6 flechas mostrou 3 formas do padrão temporal: 1) músculos afetados pelas fases e músculos afetado por todos/alguns fases nos blocos de 6 flechas, 2) músculos afetados pelas fases e músculos não afetados por todos/alguns fases nos blocos de 6 flechas e 3) músculos não afetados pelas fases e músculos afetados por todas as fases nos blocos de 6 flechas. Os músculos não afetados fases pelas fases/blocos mantem a atividade elétrica muscular ao longo dos intervalos pela sustentação da demanda muscular. Correlação cruzada entre os músculos motores mostrou que os músculos do antebraço obtiveram relação inversa entre eles. Outros músculos motores apresentaram alta correlação entre eles. Músculos posturais m. Multifido Lombar, m. Latíssimo do Dorso, m. Trapézio Superior apresentaram alta correlação com todos os músculos posturais. Músculos motores e posturais mostraram que m. Tríceps Braquial, m. Peitoral Maior Clavicular e m. Deltoide Posterior teve alta correlação com todos os músculos posturais. Em conclusão, a atividade elétrica muscular aumenta a demanda na fase antecipatória e diminui na após queda do clicker. Existem 3 caminhos na comparação das fases e os blocos de 6 flechas: afetado pela fase e 1) músculo afetado/2) músculo não afetado por todos/algumas fases nos blocos, 3) músculo não afetado pelas fases e afetado por todos as fases nos blocos. A correlação cruzada entre os músculos motores mostrou que os músculos do antebraço obteram relação inversa entre eles. Músculos posturais m. Multifido Lombar, m. Latissimo do Dorso, m. Trapézio Superior foram altamente correlacionados com todos músculos posturais. Músculos posturais e motores mostraram que m. Triceps Brachial, m. Petoral Maior Clavicular e m. Deltoide Posterior mostraram alta correlação com todos os músculos posturais.

Palavras-chave: Tiro com arco. Biomecânica. Eletromiografia. Atividade muscular. Controle motor.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
APA	Anticipatory Postural Adjustments
m. BBL	m. Biceps Brachii Long Head
COM	Center of Mass
CNS	Central Nervous System
CPA	Compensatory Postural Adjustments
m. DEP	m. Posterior Deltoid
EMG	Electromyography
m. EXL	m. Extensor Digitorum
FITA	*Fédération Internationale de Tir à l'Arc*
m. FXL	m. Flexor Digitorum Superficialis
m. LDO	m. Latissimus Dorsi
m.	Muscle
MVIC	Maximal Voluntary Isometric Contraction
M	Modulation
MUAP	Motor Unit Action Potential
ms	milliseconds
m. MUL	m. Lumbar Multifidus
m. PEM	Pectoralis Major Clavicular Head
Pre-APA	Pre-Anticipatory Postural Adjustments
m. RAT	m. Rectus Abdominis Anterior
SENIAM	Surface Electromyography for the Non-Invasive
m. SEPS	m. Serratus Anterior pull string
m. SESB	m. Serratus Anterior stabilizes the bow
m. TRZ	m. Upper Trapezius
m. TB	m. Triceps Brachii

SUMARRY

1 INTRODUCTION

Central nervous system (CNS) preserves stability and balance of posture when disturbed (2) by the anticipatory postural adjustments (APA) and compensatory postural adjustment (CPA) (1). APA is triggered voluntarily before the task by modulating activity of postural muscles and attenuates disturbances caused by body segments motion during the task (1,3). CPA is the compensation phase when postural muscles are activated to restore stability of body after movement (4) by reflex responses (2). Combinations of APA and CPA are the postural strategies to sustain the body's balance. These postural strategies are important for performance in sports.

Performance in archery is measured by scoring hit in target. In Olympic Games, there are 12 blocks of 6-arrows. Archery depends on consistency, precision, and accuracy. Consistency in archery depends on archer's atitude (5). Muscles are important to maintain correct posture during the arrow release (6). Thus, based on literature highlights about the importance of balance and posture in archery, we hypothesized that analyzing the muscular electrical activity through balance and APA and CPA will clarify the postural strategies to maintain body balance and stabilize external disturbances to release arrow. Ability depends on interaction among the subject, the bow and arrow during shooting (5). Shot must overcome any disturbances, making the release phase as reproducible as possible across blocks shots (7).

Archers coordinate agonists and antagonists forearm muscles (8,9) by co-contraction or reciprocal inhibition. Co-contraction minimizes external interference in archer during shooting (10). Other variables affect performance simultaneously (11); for example, agonist and antagonist muscles stabilize the joint by increasing stiffness and decreasing disturbances, mainly for tasks that requires accuracy. Co-activation can increase joint stiffness (slope of torque-angle relation). Initial adjustment under new condition during a reaching movement is to increase the co-activation, thereby increasing joints stiffness. This strategy deviates less from the intended trajectory. As the internal model adapts to the new condition, the heightened levels of muscle activation, and joint stiffness are reduced back to normal levels (12). Agonist muscle generates torque in the same direction of joint action; while, antagonist muscle creates torque in the opposite direction to the joint action or against another muscle referred to, the antagonistic muscle opposes the movement with relaxation or contraction of the muscle (13).

Research in biomechanics of archery describes the types of coordination and muscle activation to release arrow (5) and has paid more attention in forearm muscles. There are two strategies in forearm muscles for bowstring release: 1) relax forearm flexor muscles or 2) contract the forearm extensor muscles (14). Suwarganda et al. (2012) showed the lack pattern of muscle activation to move the shoulder during archery (6); while, Stone (2007) showed the possibility to predict shooting performance based on the tension on the bowstring and found similar activation of m. Trapezius, m. Biceps and m. Extensor Digitorum in different string tension strategies (15). For Tinazci (2011), as a result of increased performance the high performance archers have the mechanical reaction time to the shortest clicker and less electrical activity (11). These studies have monitored few different muscles, based on the inseparability of muscle activation in phases of the movement. Thus, it is not clear the muscle activation patterns during shooting.

Ganter et al. (2010) suggest that the archery analysis should look at the individual elite athletes performance. Each subject can be investigated about its own strategy during shooting (16). Ertan et al. (2003) suggest checking the role of other muscle beyond forearm muscles (17). Elite archers release the fingers 25ms before put arrow (18). Finally, APA and CPA have not been studied within the archery. This scenario induces the main question of this study: What is the temporal pattern of muscle activation during shooting an arrow in archery? Describing such activation pattern, how important is the coordination of temporal pattern of muscle activation to shoot an arrow to understand muscles activity in shooting an arrow?

The answers to these questions are the center of this dissertation. This study clarifies how the upper limb muscles are activated in shooting an arrow and provide information to improve performance. Understanding how muscle anticipation provides information about athlete. The study of comprise the muscle responses after the release arrow understand how the shooting movement disturbs posture. Analysis of co-contraction of forearm and trunk can explain the role of muscles to motion. This study sought to understand the postural adjustments to release arrow.

1.1 PROBLEM

The research problem is based on the understanding of muscle activation strategy and is formulated through the following questions:

- How is the EMG temporal pattern of upper limb muscles of archery athletes in the task of shooting an arrow?

• How is the coordination of the temporal pattern of the upper limb of the set of muscles of the archery athletes on the task to shoot an arrow?

1.2 OBJECTIVES

The main objective of this dissertation is to analyze the muscular electrical activity to shoot an arrow. The specific objectives of this dissertation are:

1. Describe and analyze the EMG temporal pattern upper limb and trunk of archery athletes shooting an arrow;

2. Analyze the coordination of temporal pattern of a set of upper limb muscles of archery athletes shooting an arrow.

1.3 HYPOTHESIS

Null Hypothesis (H_O) of this study: H_{O-1}: Electrical activity of muscles analyzed in the task of shooting an arrow at the target has the same temporal pattern.

Alternative Hypothesis (H_A) for null hypothesis is: H_{A-1}: Electrical activity of muscles analyzed in the task of shooting an arrow to the target does not have the same temporal pattern.

1.4 JUSTIFICATION

During the shooting has been the increased use of larger proximal muscles because objective greater tolerance to fatigue than the small distal muscles, the proximal muscles may include the neck muscles, shoulder and arm (6). Even with this finding is known that the ability in archery depends directly on the interaction between the subject, the bow and arrow during shooting. Research in biomechanics archery describes different types of coordination and muscle activation during shooting athletes (5). Ganter et al. (2010) suggest that the analysis in archery assess the individual performance of elite athletes, each subject can investigate to collect information on the strategy used for the shot (16). For Tresch and Jarc (2009) the studies should examine other behaviors with the widest range of behavioral conditions to assess whether the structure in the variability of muscle activation patterns consistent with muscle synergy (19). The study of synergy can help clarify the use of electrical activity strategy to release arrow. Ganter et al. (2010) propose that future studies need to examine successful strategies in archery (16). According to Suwarganda et al. (2012), electrical activity performed by the archers is varied and shows an individual way to influence score and speed (6).

Ertan et al. (2003) highlight that the studies about archery should check the role of muscles of the upper limbs, further the forearm muscles (17). This study analyzed the muscles have not explored in literature and electrical activity through coordination to contribute to the clarification of muscle activation strategy during the shooting of elite archers, analyzing muscle co-contraction strategies still undefined by the literature. The study of muscle coordination can help you find the muscle activation strategy during shooting to understand the complexity of the movement performed by the archer. One study analyze synergy during the shooting showed the kinematic parameters of spatial orientation of the laser pistol. To hit target occur fluctuations in the degree of freedom of the joints, control strategy is selective and aims to succeed in target hit (20). The authors report the same task as in archery: shoot. However, this study not has the degree of transference reported for other sports.

This study proposes shorter intervals, just like Kolayis and Ertan (2016), 3 periods: 2 seconds before and 1 second after clicker fall (21) and Ertan et al. (2003) (17) and Ertan (2009) (10) 1 before and after clicker fall. These intervals tested H_A of this study, in order to verify that the temporal pattern indicate muscle activation strategy to release arrow to understand the complexity of the movement performed by archers. Interval was chosen to check how the pattern of muscle coordination in each APA, CPA and Modulation (M). The intervals of interest were different from those found in the literature so far in this study every 100 milliseconds per interval and literature one second for each interval of temporal pattern (10,17,21). We applied different epochs to understand the evolution of the muscle activation pattern. While, other authors analyses time interval from 900 to 1500ms in EMG because it includes the full-draw and aiming phases before the release and follow-through phases just after clicker fall (17,18), we have created a sequence of 6 100-ms-epochs. Sixty miliseconds of interval did not change statistical results (7).

Only one has looked at postural stance after releasing arrow. Both phases (before and after release arrow) are important in the shot (23). Our study verifies postural adjustments through analysis of muscle activity. In other respects, archery is a potential sport that may potentially success in the World Championship, Olympic Games in Rio (2016) and in Tokyo

(2020). Therefore, research in this sport can be directly relevant to athlete's performance during championship (24). Finally, using temporal pattern of the shot offers coaches and scientists a straightforward method of data collection and analysis to determine the effect over time (25).

Coaches need better techniques to evaluate athletes. As the traditional evaluation performed by visual inspection seems insufficient for analysis of these aspects the simultaneous investigation of different kinds of variables, including kinematics, forces and EMG is required. For understanding of the shooting motor action with deeper way, the relationship among these variables has to be considered in a quantitative and qualitative way. Quantitative multifactorial approach can validate a variety of motor strategies used by an individual or among individuals to accomplish a specific goal and to identify common components that may exist across different strategies. Biomechanics can evaluate and compare individual strategies and techniques, compare level of archers, compare one subject technique with the profile of an elite archer, and compare one subject motor and technical along the season to test coaching theories (26).

For Ahmad et al. (2014) application of biomechanics in archery is very useful because helps control of muscle movement and reducing fatigue consequences that may occur, possibly causing serious injuries over time (24). Joint motion is crucial to analyze the human movement and to understand how or why injuries occur. In compliance with the biomechanics principle in archery, the forces acting on the bones should be maximized; while, the force acting on the muscles should be minimized to reduce the injury impact. This force should be applied more on bones than on muscles because bones do not get tired. From a biomechanical point of view, archer handles with the breakage of the static balance of forces between the external tension and his/her muscular forces at the time of shooting (27). Analyzing the aiming process associated with archery shooting is an established procedure for individual performance evaluation. Each of those systems can be used to gather information regarding the aiming strategy used by elite athletes (16). In the same way, the analysis not always by technique due to variations in skill and positioning are often small and the movements are often difficult to detect visually (28).

APA minimizes the effects of disturbance, but not rule out the existence of CPA. It is not clear the interaction between APA and CPA to preserve balance. APA could reduce demand for large CPA resulting in better balance control; it needs to be investigated for further clarification. Differences in EMG patterns in APA and CPA could be attributed to differences: 1) two control processes, 2) differences in disturbance magnitude or 3) combination of both (29,30).

2 LITERATURE REVIEW

2.1 ARCHERY

Archery can be defined as a non-contact and static sport that requires muscular strength, upper body endurance and high levels of stability. These performances variables are required specifically at the trunk, shoulder girdle and for both arms to ensure shooting accuracy, and score of the shoots which eventually determine the winner (7,10).

Archery has been practiced for millennium, with the current earliest archaeological recordings dating back to 65.000 B.C. The role of archery has progressed from a necessity for survival and hunting through warfare, a recreational pastime, to become an Olympic sport (25). In almost all cultures in the world was created a form of use the archery and equipment, for the survival, combat and competition (31,32). Archery have long history and use in both hunting and warfare until the invention of the gunpowder musket (33). France and Spain depict archers in hunting scenes and numerous Neolithic archaeological sites. China, Persia, Egypt, Greece and Rome had archers in their army. Gunpowder radically altered the status of archery. Britain archery persisted in high society as quasi-militaristic recreation (34). Prehistoric drawings show a practice about 25.000 (31) the 20.000 years BC (35). Philosophy and traditional training of the sport triggered to the modern Olympic style. Archery has institutionalized as a sport creating regional and national associations for its regulation, practise as a sport has been questioned on several occasions. Gradually it became object of studies of some areas of performance (32).

Winner scores in archery tournaments have become higher and higher (33). The insertion of the archery in the Olympics was in 1900 in Paris (France) with the participation of the women in the following Olympiad in Saint Louis (United States) in 1904. Archery in Olympic Games was held until 1920 in Antwerp (Belgium), and at the 1972 Olympic Games in Munich (Germany) it was reintroduced into the competition (36,37). Recurve bow (deflexed) is used in Olympic Games, this is the evolution of traditional bow (long and straight bow) and a previous version of the most contemporary compound bow (with cables and pulleys) (35). Archery have been highly refined and improved as sports equipment by modern technologies (33).

Federation International de Tir a l'Arc (FITA) was founded on September 4th 1931 in Lwow (Poland) and is currently called World Archery Federation since 2011. This institution promotes and regulates archery worldwide in conformity with Olympic principles. Standard FITA targets are marked with 10 evenly spaced concentric rings, which generally score values from 1 to 10 assigned to them. There is an inner 10 ring called the X ring, which serves as a tiebreaker. The number of hits may be taken into account as another tiebreaker (38).

Archery is seen as a sport that involves driving arrows with a bow to the target in the course of shooting (39) is one of such non-contact sport that has evolved from bow and arrow weapon used in wars and hunting into competitive and recreational game and its popularity continues to grow since being included in Olympic Games (40). Presently it has turned into a recreational activity as well as a game (39). Archery have been highly refined and improved as sports equipment by modern technologies. In fact, the winner scores in archery tournaments have become higher and higher (33). Archery is classified into two major categories by FITA: 1) recurve or Olympic archery and 2) compound archery. In addition, different sub-classifications within traditional archery types also exist, e.g. Turkish Archery, Kyudo (41).

Olympic competition requires archers to shoot a 72-arrow ranking round to a target of 70m, with the elite 64 archers progressing to a series of classification rounds. In the classification rounds, each archer will shoot three arrow groups called ends. The archer with the highest score gets two points for winning the end, with the first archer to gain six points advancing to the next round (42). Target face is 1220mm in diameter and features 10 rings that increase by 61mm increments. Scoring system ranges from 10 being the highest (hitting the center circle) to zero being lowest (arrow has missed scoring zones completely) (23). Olympic outdoor archery competition current modifications to the rules change style of shooting, for example, one arrow has been further lessened to 30s as the athletes shot consecutively in the rounds of Olympic Games. Previously competitors could take as much time as necessary across every arrow (39).

World Archery (2015) described that Outdoor Target Archery rounds may be shot by both Recurve and Compound archers, in separate divisions. However, only recurve division competes in the Olympic Games. World Archery Standard Round may only be competitively shot by athletes conforming to the World Archery Standard Bow Division: 1) 50m Round for Compound release of 72 arrows on the 80cm target face, 2) 60m Round (for Recurve) for Cadets and Masters release 72 arrows shot at 60m on the 122cm target face and 3) 70m Round (for Recurve) release

72 arrows at 70m on the 122cm target face. Third division was used in experimental design of this study for analyzing release arrow (42).

The distances are: 90, 70, 50 and 30 m for men; 70, 60, 50 and 30 m for women. The large number of shots (144) undertaken in 1 day by competitors requires a very reliable action (43). Archer aims the highest possible point in 90 m, 70 m, 50 m and 30 m distance, by firing 144 arrows that are divided into these 4 varied distances. In each of the distances, archer release 36 arrows. FITA recurve round demand the highest possible total score by firing 144 arrows in 90 m, 70 m, 50 m and 30 m distances precisely onto the target with 122 cm diameter of target face for 90 m and 70 distances; and 80 cm diameter of target face for 50 m and 30 m distances. Score in recurve archery, archer aims the highest possible total score to release 144 arrows in 90 m, 70 m, 50 m and 30 m distances precisely onto target with 122 cm diameter of target face for 90 m and 70 distances; and 80 cm diameter of target face for 50 m and 30 m distances (44).

Archers have 4 or 5 days training sessions in a week, the duration of a single session is about 3 hours, the number of arrows they shoot in a single session ranges between 50 and 300 with the mean of 168.45, and their drawing weight is 18.063 kg. Multiplying the average number of arrows in a single session with again average drawing weight equals 3042.72 kg in a single session. Thus, they work out about 3 tones in a single session and 13.5 tones in a week (45). In addition, during the archery competition, an archer shot during the whole day and drawing the bowstring weighing about 14-22 kg. One archer release 144 arrows except for the test shots. So, an archer pulls an average of 20 kg during every single shot and totally 144x20= 2880 kg. In addition to that an archer walk about 3600 m to pull out the arrows from the target. It is thought that, an archer draw almost 3000 kg and walk about 3,5-4 km in a single day competition period. Moreover, these quantities increase twice or three times during training period. These numbers are paid attention and strength continuity is important in archery. However, bow drawing weight, which is pulled during each shot, does not constitute maximal strength (21). Force demanded to draw the bowstring back until full drawing position is termed the bow weight. When the archer has drawn the arrow back to his holding position, full draw has been reached (46).

2.1.1 Clicker

Clicker a piece (a spring-loaded lever (17)) of spring steel fixed in 5 cm long and 0.5 cm

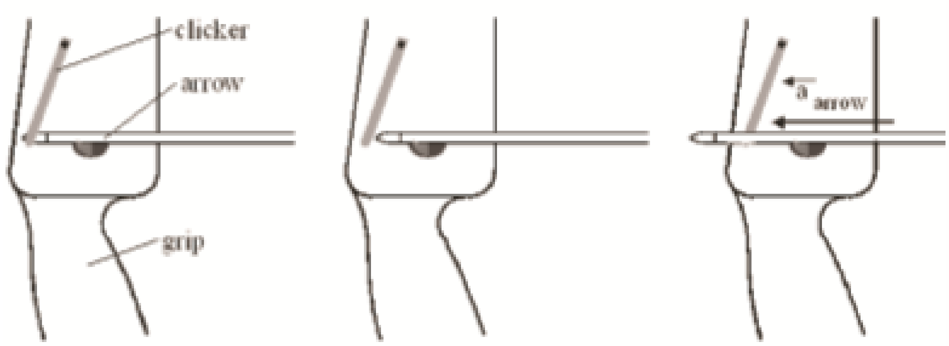
(27), as follows in the figure below:

Figure 1 - *Clicker*

Source: Adapted from Merlin Archery (2017) (47)

Figure 1 is an example of clicker. Each arrow can be drawn to an exact distance and a standard release can be obtained using clicker (17). Audible impulse from the clicker and determines when bowstring is released (43). Below follows a description of how to release arrow.

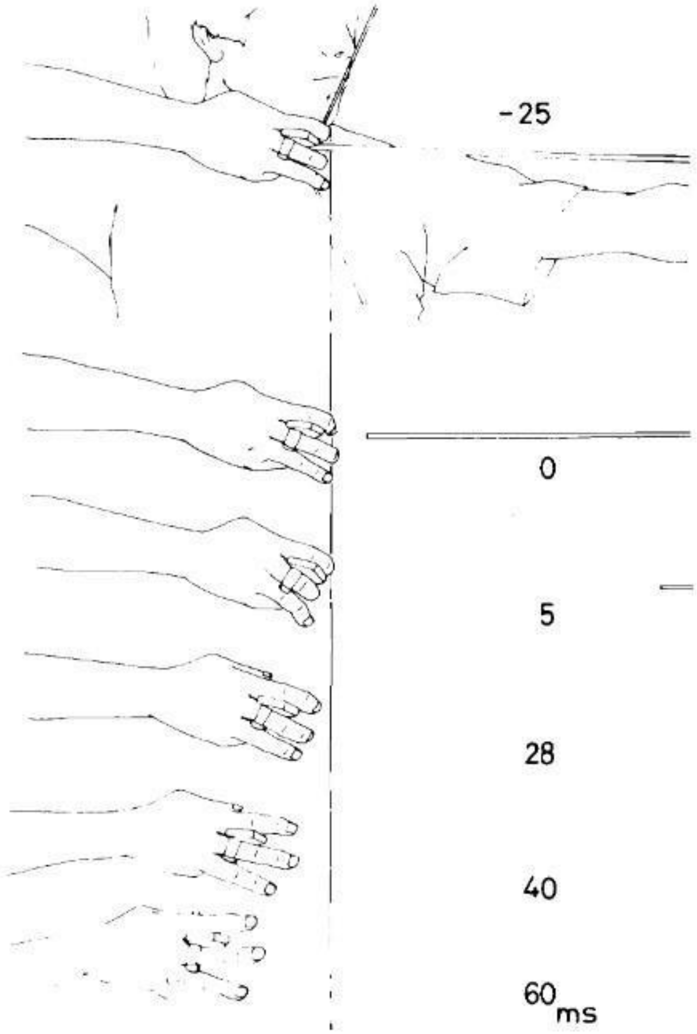
Figure 2 - Clicker and the process of shoot



Source: Adapted from Heller (2012)(25)

Figure 2 show the clicker in the shot sequence. Firstly, archer draws the bow holding the arrow between the bow and the clicker, clicker presses the arrow against the riser. Thereafter, the archer pulls the arrow back until the clicker slips over the arrowhead and causes a click with sound stimulus. Finally, the archer thrown the string and arrows is accelerated (27). Some studies have also used the action before and after clicker to determine the beginning of the interest interval with the sound stimulus signal by means of this device (9–11,17). Elite archers presented a faster reaction to the clicker fall than that of the beginners and non-archers (17).

Figure 3 - Shot of elite archer while being scanned with high-speed camera



Source: Adapted from Nishizono et al. (1987)(18)

Figure 3 show the shot of elite archer in high-speed camera (unspecified sampling frequency), release time in 0ms. From 25ms before releasing arrow, fingers begin extension (18).

Archer throws the arrow when the bowstring is released after audible impulse of clicker to produce release arrow pattern (43). Each arrow can be throwing to an exact distance and a standard release can be obtained by means of clicker. The archer should react to the clicker as quickly as possible. In particular, a repeated contraction and relaxation strategy in the forearm and pull finger muscles should be developed for this reason. Archer reaction to clicker fall is important to develop a fine coordination of m. Extensor Digitorum and m. Flexor Digitorum Superficialis in drawing arm. Elite archer reaction to clicker fall faster than beginner and non-archers by m. Extensor Digitorum contraction, elite archers release approximately 100 ms after clicker fall while beginners nearly 200 ms and non-archers 300 ms (17).

2.1.2 Description of the movement

According to FITA (2003), the steps of shooting include four stages: 1) preparation movements, 2) effort production period, 3) critical instant and 4) follow-through (48). In order to, some researchers describe the shot as a three-phase movement: the stance, the arming, and the sighting (43,49). On the other hand, Nishizono et al. (1987) divide the shot into six stages: bow hold, drawing, full draw, aiming, release, and follow through (18). Archer pushes the bow with extended arm, the arm is statically held in the direction of the target, other arm exerts a pulling of the bowstring until the release (17,43). Release phase must be balanced and reproducible (17,18). A majority of competitive archer shoots using the three-finger grip release. The fingers release is the point on which the bowstring slips off from the finger tips (50).

Drawing phase the archer pulls the bowstring with one arm and holds the bow with the other arm. Archer put the bowstring in the face (places tip of the nose, the lips, and the chin) in the final position of the drawing phase. During the draw position the archer should both aim at the target and release the bowstring without disturbing the aiming position and the lateral deflection of the string. Release phase must be well-balanced and highly reproducible to achieve commendable results in an archery competition (7,43,49). Releasing bowstring requires use of forearm muscle groups. The archer is supposed to react to an auditory stimulus from the clicker fall by coordinating the forearm muscles (7,17). Then, archer could produce a pull–push balance between drawing and bow arm, and perform a consistent release bowstring (7,18).

Clear definitions of key performance indicators are needing to allow repeatably. The consensus of definitions is not clear. There is no delineation between a release arrow phase within the cycle (25). It attempts to group the way the movement is described in the following paragraphs. Archer propel arrows with a bow to the target during shooting (24) and arrow is shot in average of 5-6 seconds, in which, archers should pull the bowstring, aim at the target and finalize the shooting (21). This is just one way of describing the shot, but the shot can be divided into phases of several forms, below follows the most cited in the literature.

Heller (2012) summarize the movement of shot and mentioned that archer draws the bow, pulls the arrow to the clicker, fixes in this position and aims. Then, it pulls the arrow through the clicker named final pull and releases the shot. Archer has to handle with the break of the static balance of forces between the external tension and muscular forces at the time of shooting (27). Tinazci (2011) (11) and Ahmad et al. (2014) (24) consider the shot in three steps: as drawing the bow, aiming and releasing. Other ways of characterizing the shot by coaches as a three-phase movement: the stance, the arming and the sighting (16,43). From the beginning of the arming phase, the archer pushes the bow and pulls the bowstring until the release. Therefore, the sighting phase is characterized by two simultaneous tasks: the sighting itself and a delicate push-pull control (43). Other studies describe the movement in more phases.

A fixed sequence of movements can be dividing the shot into six phases: bow hold, drawing, full draw, aiming, release, and follow-through (18,26,35). Afterward reaching the full draw position, archer perform different tasks concurrently: the aiming (or "sighting"), a push-pull control by the bow and draw arm ("final pull") followed by the release (16). Kolayiş and Ertan (2016) suggest more details as high scores in the competition; using the time effectively, releasing should be stable and the same each shooting and strong posture is important. Furthermore, position of sight on the target when releasing arrow, is determining place which arrow's destination (21). Alternatively, Humaid (2014) described the shot technique consists of 9 phases: 1) stance (position/ standing posture), 2) nocking (putting arrow onto string), 3) hooking and gripping (preparing drawing fingers and gripping position), 4) before draw, 5) drawing (full draw), 6) aiming and expansion (aiming onto target), 7) release (releasing string and arrow), and 8) follow through (further movement) (44).

Archers use a consistent sequence of movements during the execution of a single shot by stance position, inserts the arrow, holds the bowstring and creates a pressure point on the bow-grip and continues with drawing the bowstring (10) and pushes the bow with an extended arm in the direction of the target, which is statically held in the direction of the target, at the same time the other arm perform a dynamic pull of the bowstring from the beginning of the drawing phase, until the release is dynamically executed (11,17,43), drawing arm bring the string under the chin to full draw position bow arm perform drawing easy with its stable movement and exhibits isometric contraction to not to move the bow position in the phases of releasing and following through. Whereas the bow arm do isometric contraction and sustain weight and vibration of bow, without disturb the flying of the arrow with its stable movement (21) and its fixed the positions of the arms (51) and to reaching to the full-draw, aiming, releasing and follow-through (10).

There are similar aspects present in all archers, such to release arrow. Strategies vary in some ways that can attribute to the skill and in other ways may not attribute to the ability. There are two ways to accomplishment full drawing position: “1) lift and hold the bow in the right position and then move the drawing arm backwards; 2) lift both arms and, simultaneously move them in the opposite direction” (26). Pull length is the period from extension of drawn bow unto the string achieve the nose, lips, and chin when the archer uses correct technique. Pull length is quantified from the notch on nock to arrow rest. Pull length is influenced through the anthropometric factors, for example: extension of arms, width of both of shoulders because in archery the asymmetric movement is performed by body sideways (44). Archer alignment is also important to release arrow. Lin et al. (2010) complement which contraction of shoulder muscles maintains alignment of arrow with target in draw position. Whilst small fluctuations in limb during steady posture is recorded during shoulder muscle activation. Small fluctuations in voluntary postural tasks are called physiological tremor (51).

Firstly, the archer draws the bow insuring the arrow between bow and clicker, the clicker presses the arrow lateral against riser. Archer retains stretch bow as long as the clicker presses the arrow lateral against the bow, while the archer aim arrow to target. At the end of the aiming phase the archer does the final pull to pull the arrow back until clicker fall across the arrowhead and causes a click. Finally, archer releasing the hand from string and arrow is accelerated to target (27). The duration of release is approximately any milliseconds (28). Prior to arrow release, the fingers must be held in a flexed position in order to maintain the grasp of the string as the arrow is being drawn and held in the full draw position. In response to the stimulus to release arrow (closure of the clicker on the bow, which occurred on average 185 ms prior to release), a decline in flexor activity would contribute to a reduction in the flexor moments acting about the joints of the fingers, facilitating extension of the fingers (49).

Principal motion of arrow caused by fast system bow–grip–limbs–string. Concurrently the arrow through the string nock point involved by the whole system in deflection. This rapid motion causes arrow deflection (52). The archer is careful to aiming target vertically and horizontally, postural sways to release arrow may adversely affect score (11,41).

2.1.3 Release pattern

Archery can be described as a comparatively static sport requiring strength and endurance of the upper limbs, in particular the forearm and shoulder girdle (17). Skill in archery is the ability to shoot an arrow to target with accuracy (17,43). High performance shooting in archery is the ability to shoot an arrow at a given target with accuracy (8,43,49). According to World Archery (2015) “a good shooting action and an efficient shooting sequence involve the interaction of input and impressions from different senses (42). These sensations and reactions include the visual picture of sight, the feel of the body, the mental state, and an awareness of the environment.” Contraction and relaxation strategy in forearm muscle in the release of the bowstring is critical for accurate and reproducible and influence the scoring in archery (17).

Coordination between the agonist and antagonist muscles of the forearm is essential in this strategy and requires a relatively long training period (17,18,28). Muscle strategies to release arrow proposed in previously studies, but not well-defined (18,28,49). In the first approach, archer release the bowstring by relaxing of flexors muscles and the force of string is sufficient to produce fingers extension (49). In the second approach, archer performs flexor relaxation and extensor contraction. An active extension of the pull fingers produce lateral deflections of the bowstring and to be less consistent with the shot-to-shot performance (17,18,49). Nishizono et al. (1987) look at m. Extensor Digitorum as the key muscle engaged in the releasing bowstring (18). Ertan et al. (2003) demonstrated the muscle strategies for different level of archers. In this study, all archers and non-archers performed an active contraction of m. Extensor Digitorum and progressive relaxation of m. Flexor Digitorum Superficialis after clicker fall (17).

While the archer performs the above steps during movement, the movement of the arrow is described in two different ways. The first phase the interplay of arrow and archer-bow from the moment of releasing the bowstring until the arrow loses contact with the bow and the bowstring, in other words, releasing of the string and leaving of the arrow from the bow. In second phase, the ballistic flight in the period from end phase 1 until arrow hits the target. Many variables can affect flying of the arrow in the first phase, and can affect negatively score (53).

Pulling the bowstring by drawing the arm includes the elbow flexed by concentric contraction of m. Biceps Brachii and m. Brachialis, the shoulder is extended by the strong concentric action of m. Teres Major, m. Latissimus Dorsi and m. Posterior Deltoid. Pectoral Girdle is protected by concentric shortening of m. Trapezius, m. Rhomboid Major and m. Rhomboid Minor. During the pushing movement of the bow by abduction and flexion of the shoulder, the shoulder is maintained in abduction by isometric contraction of m. Middle Deltoid and is then rapidly flexed by m. Deltoid Anterior and m. Pectoralis Major, assisted by m. Coracobrachialis and m. Biceps Brachii Long Head, all of which work concentrically. In the collective movement to release arrow, the bow arm is responsible for pushing the bow and adjusting the placement of sight on the target by resisting the force from the drawing arm (7).

2.1.4 Demand in archer

A fixed sequence of movements for performs bow holding, drawing, full draw, aiming, release and follow through stage. The phases enable the subject hold reproducible releases for achieving and maintaining good results. The implies are: 1) programming of the proper movement sequence during the different phases, 2) the control of body segments action, 3) the body and bow equilibrium maintenance. Authors related that complex motor task which involves multijoint coordination, a distinctive feature of motor system is maximally exploited, namely potential to execute same motor task through different combination of motor actions (26).

Many factors determine the performance profile of an athlete, for example anatomical, physiological and psychological (28). There are internal and external factors that influence the archer during shot according to Kolayiş and Ertan (2016) (21). Internal factors are: reaction time, concentrating on the target, fitness level, technique and tactic properties, psychological condition, and readiness for competition. External factors are thought to be the material used should be suitable, adequate and modern, the weather condition should be appropriate for archery shooting, environment should be silent and financial situation should be adequately.

Other author described some matters to consider: 1) physical conditions, covering: arms muscle strength, body muscle strength, legs muscle strength, muscle durability, aerobic capacity, flexibility, body posture (pull length), coordination between eyes and arms; 2) techniques, covering: basic archery technique, instruments tuning and suitability to body condition and posture, compensate, instrument quality; 3) tactic, covering: control of archery order and; 4) Psychology, covering: motivation, confidence, sportively, anxiety, self-control, tenacity to overcome any pressure, concentration, among others (44).

High performance shooting in archery is defined as the ability to shoot an arrow at a given target with accuracy (7–9,17,25,43,49), because both skilled and elite archers use equipment of same general quality, differences between their performances must be highly dependent upon their own controlled actions (45,54). Skill in archery is defined as the ability to shoot an arrow to a given target in a certain time span with accuracy (21), it depends on the interaction between the subject, the bow and the arrow when shooting (5). Accuracy sensitivity to any change in the parameters of the archer-bow-arrow system should form the basis for an evaluation of any of the system's elements and their interaction with each other (53). For example, the elite, middle and beginner archers have high accuracy with high precision, low accuracy with high precision and have high accuracy with low precision respectively (38).

Precise nature of the sport, minimizing movements during the aiming phase allows for greater repeatability and consistency of this closed loop skill (23,55). Archery can be described as a comparatively static sport requiring strength and endurance of upper body, in forearm and shoulder girdle (21,46). Good results in an archery competition demand a well-balanced and highly reproducible release during the shooting (24). High performance in Olympic archery is defined as the ability to shoot an arrow at a given target with high accuracy even with the large number of shots undertaken in one competition into account; the shooting movement of the archer is required to be highly reproducible (16). The consistency postural of an archer at the arrow release is commonly perceived to be an important determinant of success. The coach provides the archer with information about postural consistency, details of which he acquires by eye or occasionally equipment (54). Postural movements potentially affect aiming stability in archery, thus contributing to chances of inconsistent hits (55). Consistency in archery shooting depends on adopting a posture in which forces between the archer and bow are correctly aligned. Muscles play an important role maintaining the correct posture and releasing the arrow. The utilization of bigger proximal muscles is thought to promote consistency due to the higher tolerance for fatigue than the smaller distal muscles (6). Besides strength and endurance, postural stability is another crucial variable in determining the outcome of every shot. An archer’s skill is evidenced in the ability to shoot the arrow to the specific target within a specific time. To achieve this, athletes need to minimize their movements in each step or phase to avoid unnecessary movements which can reduce stability, thus, minimizing chances of hitting the center target. An archer movements must be as precise as possible, coping fast with postural instability (10,17,55).

Several studies offer some variables about description of parameters of archery (39). Scientific research of archery athletes training permeates the problems of body moves modulation, physiological mechanism of movement habits, smoothing or removes of mistakes to release. Some research only partly decide problems of technical training in archery (56).

Final pull and the release arrow were related in some earlier research. Electromechanical devices detect clicker fall moment in bow, arrow release, and contact-loss of the arrow with the bowstring with high temporal resolution, which is very time-consuming and complex to affix. Another approach was to fix an acceleration sensor at the bow riser detecting mechanical vibrations. Biomechanics research of archery have frequently described the different coordination and muscular activation to release arrow (5). In addition, the literature not much attention for understanding the types of injuries inflicted on peripheral nervous system in archers (40).

For the authors, the present understanding and its mechanics derived from empirical observations made by coaches and athletes. In contrast, the majority of studies concerted effort to develop the scientific cognizance of various technique aspects of archery, which in a larger concentration in EMG investigations (25).

2.1.5 Muscle electrical activity in archery

To shoot the archer position the bow with his arm extended toward the target, while the other arm pulls the bowstring, starting the stretch of the bowstring to release arrow (7,11,17). The move to reach out and pull the string should not disturb the output of the arrow, so the phase of the arrow release becomes reproducible across the blocks (7). Archery needs static strength and endurance in the upper body, especially the forearm and shoulder girdle (7,11,17). Archers produce the coordination between the muscles agonists and antagonists forearm during shooting (8). Co activation in muscle is characterized by simultaneous activation of muscles in joint action describing agonist and antagonist (12,57). Action of agonist and antagonist stabilizes joint by increasing stiffness and decreasing effect of disturbances by mechanical effect (12).

Two approaches describe the muscular strategy of forearm during shooting. The first approach suggests that the archer must release the bowstring by the sudden relaxation of the muscles that keep the bending of the fingers on the string and this is sufficient to produce extension. In the second approach, there is relaxation of the flexor muscles and the contraction of m. Extensor Digitorum. The authors report that this strategy not well-defined (49). Due to this approach that found the archer's forearm strategy to release arrow, still unclear, it believed that with this study the APA and CPA responses showed a new look at the temporal level and could clarify the archer individual strategy. The strategy is the unique solution with the participation of neuromusculoskeletal components for the performance of the motor task (58).

EMG of m. Extensor Digitorum and m. Flexor Digitorum Superficialis that skill levels can determine the shooting techniques (8). Electrical activity of forearm muscles determinate the shooting technique, indicate progression and possible talent for sport that because there is a decrease preparation phase and increased muscle coordination forearm. The principal difference between elite archers and beginners was that elite archers show greater activation of m. Extensor Digitorum and contraction of extensor muscle groups, muscle contraction this strategy does not interfere with movement and increases the chances of hitting target (10,17).

The different levels of skills affect the ability to reproduce similar motor patterns by neuromuscular control of m. Trapezius, m. Biceps and m. Extensor Digitorum (28). Suwarganda (2012) analyzed three archers and found that they possess the individual strategy of muscle activation in m. Triceps, m. Trapezius and m. Medial Deltoid (6). The selection of the correct shooting technique results in increased accuracy archers and non-archers, even though it has an unnecessary activation of muscle by tension and muscle fatigue (15). For Tinazci (2011) high performance archers have the mechanical reaction time to the shortest clicker and less electrical activity as a result of increased performance (11). During aiming, an archer holds the stretch bow while the clicker presses the arrow lateral against the bow; clicker is a small piece of metal (27). Finally, Ganter et al. (2010) describe that analyzing the aiming process associated with archery shooting established procedure for individual performance evaluation of archers (16).

Part of studies analyzing archery were based on two muscles: m. Extensor Digitorum and m. Flexor Digitorum Superficialis (7–10,17). However, five studies show activity of forearm muscles. Clarys et al. (1990) analyzed the muscles m. Extensor Digitorum, m. Brachioradialis, m. Biceps, m. Trapezius on the side pulling the bowstring; while on the side that holds the bow, they analyzed m. Trapezius, m. Brachioradialis, m. Extensor Digitorum, m. Flexor Digitorum Superficialis, and m. Triceps (28). However, Suwarganda et al. (2012) studied m. Triceps on both sides, m. Deltoid and m. Trapezius (6). Stone (2007) investigated m. Trapezius, m. Biceps and m. Extensor Digitorum (15). Tinazci (2011) described m. Extensor Digitorum, m. Flexor Digitorum Superficialis, m. Deltoid and m. Trapezius (11). Nishizono et al. (2007) analyzed m. Extensor Digitorum, m. Flexor Carpi Ulnaris, m. Biceps, m. Triceps, m. Deltoid and m. Trapezius (18). Finally, coordination between agonist and antagonist of forearm muscles produce by co-contract, this coordination protect movement from interference to release arrow (10), it is known many variables can affect performance simultaneously (11).

2.2 Postural adjustments

Task in archery is the same (shoot the target), the practice in these conditions would be more effective for learning, although it suggests the varied practice to acquire the ability to deal with new situations; not least the practice in constant situations and little invariable (59). Shoot motion is desirable that the arrow aims to balance and high reproducible (17,18). Skill level in shooting is related as ability to reproduce identical motors patterns through the neuromuscular control (28). Stable sequence requires the voluntary movement skills to perform the movement (18,60,61). The shot should be done with less disturbance by means of reproducible phase to release arrow across the blocks (7). Thus, consistency in archery depends on the posture that the archer adopts the forces between the archer and bow are aligned, the muscles perform an important to maintain the correct posture to release arrow (6).

Vertical position is inherently unstable because the location of the center of mass (COM) and multiple joints between the legs and the body. When a person standing performs fast moving and/or interacts with external objects, the mechanical coupling of the body segments lead to postural disturbance that can influence the balance (2). There are two kinds of balance disturbance in humans during standing or walking: internal (movements involving the body segments) and external disturbance (induced externally). These types of postural disturbance create dynamic, inter-segmental forces that alteration in COM proximity to limit of base of support, disturbance can affect the body's stability (29,30). CNS preserves stability of the posture by APA and CPA (1). CNS uses them to maintain and restore balance when disturbed (2).

APA is a pre-programmed action starting voluntarily (1,3) and reflect a feedforward control and the changes are seen in the background activity of muscles (29,62,63), it is related on previous experiences and learning of subject (64). APA are the changes in the activity of the postural muscles before postural disturbance self-generated, for example, before the rapid voluntary movement (1,3), known as focal movement occurs prior to external disturbance can lead to imbalance. Its latency is approximately 200 milliseconds (3). APA modulated by voluntary perception of task start and is evidenced by agonist activity/antagonist or synergist, or the kinetic action of the movement, important relationship between APA and the generation of synergies that control the execution of movements. This is the movement of the preparation for the possible disturbances caused by the displacement of body segments. The APA has its central nature and maintains equilibrium with minimal energy (1,3). APA control COM position activating muscles of the trunk and legs before the next disturbance of the body, minimizing the risk of loss balance (2). The second part is the compensation phase, wherein postural muscles activated on after main trigger by feedback; they stabilize the body (4).

CPA reflect feedback control wherein changes in muscle activity are triggered by feedback of sensory signals and serves as COM position restoration mechanism after a disturbance has already occurred (2,63); for example, all postural activity that takes place after the completion of the focal movement or external disturbance, this may or may not be associated with postural adjustments of the focal movement. CPA ensures stability after the disruption caused by the movement (3) because CPA minimizes the destabilizing effects caused by predictable and unpredictable disturbance (64). Activation sequence of postural muscles depends on task because the form of preparation for movement is specific (4).

APA and CPA magnitude depends on direction and degree of postural disturbances classified as either internal (generated by forces and torques developed during the movement of subject) or external (produced by forces around the subject), but is not limited to this (64). It is known that the magnitude of APA depends on the direction and magnitude of disturbance and body stability. APA are influenced by characteristics of task used to induce a disturbance, body configuration, and fear of falling (29,30,62). CPA depends on the direction and magnitude of disturbance, dimensions of the base of support, characteristics of predictability of the disturbance, instructions, and participation of a secondary task such as holding an object in the hands (29,30).

There are several ways to perform a motor task from muscle strength combinations in the joint (14,65). In choosing how to do the task is the selection process and/or optimization to perform the move (65). CNS indicates and active the muscle, when there is variation task the signal control changes, this leads to parallel changes in the muscles used together in motion. The muscles involved to accomplish the task organized into groups that hold in common. These muscles are a CNS strategy to reduce the number of degrees of freedom to be controlled for task execution and can be called synergy (66).

Postural synergies are considered constructive units that the CNS uses for the construction of the control signals joints and muscles, the combination of control signals to various muscles to ensure the stability of the limb or whole body by anticipation of the disturbance (1). Muscle synergy has been suggested as a solution to the problem of degrees of freedom in the motor control, instead of controlling all motor units and muscles involved in the task, it uses muscle synergies of CNS to produce the behavior to control of fewer variables, optimizing so the execution of the movement with the solution of coordination (19). The approach to optimization allows choosing a single motor solution to the performance problem system.

The organization of the structures involved in the implementation of the abstract movement is synergy. Measurement of synergy can use different basic variables, such as kinetics, kinematics and EMG on various tasks (67). Synergy is the neural organization signals output elements (muscles, joints, effectors) of a multi-element system, ensuring stable performance of the task(1). For Latash, Scholz and Schöner (2002) synergy confirms the principle of minimal interaction, if during the execution of the task a wrong element; the other element modifies its contribution to minimize the initial error (68).

2.3 Stretch reflex modulation and pre-programmed reaction

The joint creates a sequence of EMG events during unexpected disturbance in stretch muscle (1). The event comes at a short latency (M1) and long latency (M2 and M3) (1,69–71) or pre-programmed reaction. M1 corresponds to monosynaptic transmission and probably represents the phase stretch. Pre-programmed reaction, M2 and M3, can be defined as muscle reactions to external signal (for example: in disturbance) prepared in advanced by the CNS and triggered by an appropriate peripheral stimulus (1).

EMG event are not clarified in the literature. Kandel et al (2012) describe that reflexes of limbs are mediated by multiple pathways, these pathways act in parallel through spinal and supraspinal pathways (72). The author cites the example of a flexor muscle of the thumb. The response has two discrete components: M1 and M2. M1 is the first response generated by the monosynaptic connection of muscle spindle afferent to the spinal motor neurons. M2 latency is shorter than the voluntary reaction time, in other words, M2 response is also a reflex. Long-loop reflexes via the cortex are of primary regulate twitch in distal muscles, whilst subcortical reflex pathways regule contractions of proximal muscles (73,74).

2.4 Postural Control

The postural system is highly adaptive, both in the short term to optimize postural behavior to a continually changing environment, and in the long term to accommodate changes in body morphology and mechanics caused by growth and development, aging, disease, and injury (72). Posture can be defined as a combination of the relative positions of body segments or of the whole body with respect to a reference frame. Postural control may refer to maintenance body segment position with respect to an external reference frame, for example to the environment or to an external object moving in the environment. Postural control may also refer to keeping the position of a segment with respect to the body itself (57). Postural control system has the function of performing the support, stability and balance (3).

Upright stance requires two actions: 1) maintaining support against gravity (keeping the center of mass at some height) and 2) maintaining balance (controlling the trajectory of the center of mass in the horizontal plane). Balance and antigravity support are controlled separately by the nervous system and may be differently affected in certain pathological conditions (72). Latash (2015) describe that postural control has two aspects: first, postural control can refer to maintaining the position of a part of the body in relation to the body or the environment (or an external object moving in the environment); second, postural control may refer to maintaining the position of the whole body or its center of mass in relation to the environment (such as the direction of gravity). Human body has several joints invertical axis. To maintain equilibrium in the gravitational field, the projection of the COM must fall within the bearing area. To maintain balance the CNS should define how interactions of movements in different joints (1).

Clinically, postural control is often equated to equilibrium control of stance. However, posture control does not end with body-on-feet balancing. Rather, we balance the head on the trunk, the trunk on the hips, or make the trajectory of an arm during reaching movement resist gravity. There are different demand in each task, depending on which muscle groups, joint, among other structures (75). Postural control is the basis of human motor control system, producing stability and conditions for movement, such as the ability to assume and maintain the desired body position during a static or dynamic activity (76). Control of posture is crucial for most task of daily living. Orientation and balance (components of posture) require continual adjustment and involved several sensory systems. Postural equilibrium, or balance, involves active resistance to external forces acting on the body. Dominant external force affecting equilibrium on earth is gravity. Postural orientation is the positioning of body segments with respect to each other environment. Depending on the particular task or behavior, body segments may be aligned with respect to gravitational vertical, visual vertical, or the support surface (72). Some lines of defense against unexpected or unbalanced postural disorders (1). Vertical posture is protected against disturbance by any lines of defense. Posture-stabilizing mechanisms differ in their relative timing with respect to a disturbance and efficacy (1,57), as in table below (57).

Table 1 - Main posture-stabilizing mechanisms

Mechanism	Time delay	Characteristics important	Positive features	Negative features
APA	< 0 ms	Based on predicting a disturbance	Feed-forward; allow preparation to a disturbance	Based on prediction; always suboptimal
Muscle and tendon elasticity	0 ms	Can be modulated (preflexes)	Act instantaneously; always against the local disturbance	Not strong enough; not task-specific
Monosynaptics reflexes	30 ms	Poorly controlled	Act after a short delay; negative feedback loops	Poor central control; jerky
Polysynaptics reflexes	50 ms	Low gain		
Pre-programmed reactions (long latency reflexes, $M_{2\text{-}3}$)	70 ms	Approximate correction	Act after a short delay; task-specific	Produce approximate correction
Voluntary actions	150 ms	Late!	Task-specific	Long time delay

Source: Latash (2012) (57)

Table 1 shows posture-stabilizing mechanism in time of EMG events. Antigravity support represents the tonic activation of muscles that generate force against the ground to keep the limbs extended and the center of mass at the appropriate height. In humans much of the support against gravity is provided by passive bone-on-bone forces in joints such as the knees, which are fully extended during stance, and in stretch ligaments such as those at the front of the hips (72). Nevertheless, antigravity support in humans also requires active muscle contraction, for example in ankle, trunk, and neck extensors. Postural synergies might be used to reduce the number of degrees of freedom of the body, in which case the system would become less variable and easier to control (77). Postural synergy is the relation of elementary variables, such as joint rotations or recruitment of muscle groups, and the goal of stabilizing posture (1). Another reason to appeal of hip and ankle strategies may be experience of use of hips for postural control (77).

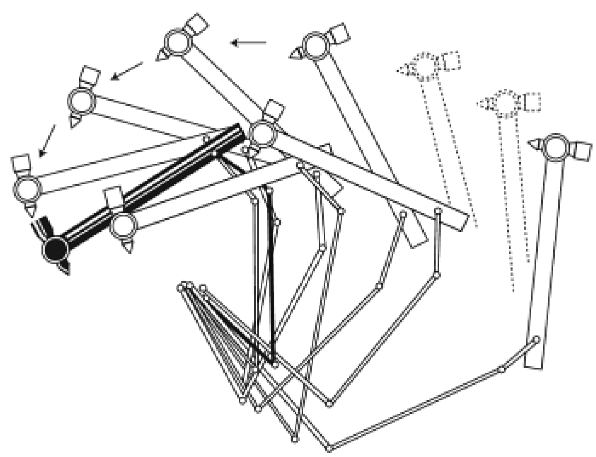
For Kandel et al (2012), tonic activation of antigravity muscles is not sufficient to maintain balance. Actively contracting muscles exhibits a spring-like stiffness that dump the body sway, but muscle stiffness alone is not enough to maintain balance. Likewise, stiffening of the limbs through muscle co-contraction is not sufficient to balance control. Instead, complex patterns of muscle activation produce direction-specific forces to control the COM. Body sway caused by subtle movements, such as breathing, is counteracted by the posture control system. Voluntary movements themselves can destabilize postural orientation and equilibrium. Rapidly lifting the arms forward while standing, for example, produces forces that extend the hips, flex the knees, and dorsiflex the ankles, moving the COM forward relative to feet. The nervous system has advance knowledge of effects of voluntary movement on postural alignment and stability and activates anticipatory postural adjustments, often in advance of primary (72).

Postural control effective is impossible without sensory information (57). Appropriate balance requires the integration of information from different sources, including vestibular, visual and proprioceptive information (1,72,76). Somatosensory, vestibular, and visual input contribute to postural control to balance and gear with differing degrees of influence as our environment changes. Many areas of the CNS integrate the sensory input to form an unified representation of the body's orientation and motion within the environment (72). CNS is arranged in a hierarchy of control levels, with the forebrain at the top and the spinal cord at the bottom. Bear, Connors and Paradiso (2007) report this motor control hierarchy as having three levels. Highest level represented by the association areas of neocortex and basal ganglia of the forebrain, is concerned with strategy: the goal of the movement and the movement strategy that best achieve the goal. Middle level represented by the motor cortex and cerebellum, is concerned with tactics: sequences of muscle contractions, arranged in space and time, required to smoothly and accurately achieve the strategic goal. Lowest level represented by the brain stem and spinal cord, is concerned with execution: activation of the motor neuron and interneuron pools that generate the goal-directed movement and posture adjustments (78).

2.5 MOTOR COORDINATION

Movements are controlled is flexible to accommodate the variability without prejudice to the task performance. The coordination of the movement is a process of controlling the redundant degrees of freedom in movement, controllable system (79). Motor coordination is related to problem of motor redundancy. CNS selects options of particular solutions offered by muscles, joints and limbs (80). Motor task can be accomplished in different ways with numerous combinations muscle strength generating the same binary sets. However, muscle activation patterns of different people that perform same task as well learned are very similar. This evidence suggests that during the control of individual muscle forces, CNS uses same specific principles for several people (65). Control uses to minimize possible errors by corrective action (68).

Figure 4 - Different positions of the arm and hammer to hit the chisel with a hammer



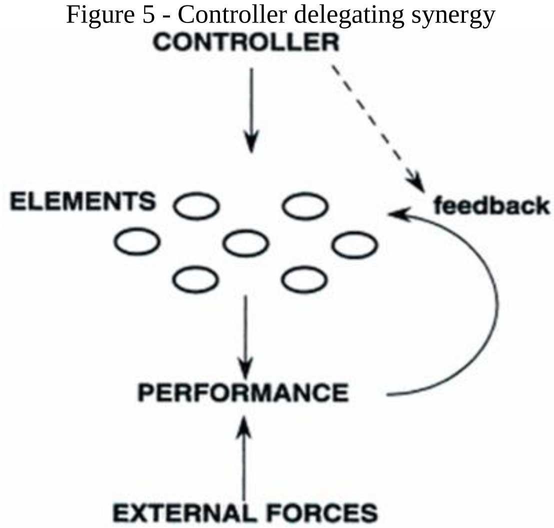
Source: Adapted from Latash (2012) (57)

Latash (2012)'s figure 4 (57), produced by Bernstein (1967) (81), shows that the variability of joint movement is greater than the variability of the end point, when the blacksmith hammers a nail. Motor variability refers to the difference between repetitions of the same task lead to different standards of performance and neural activation and engine and how to vary the kinetic values of muscle strength, kinematics and EMG (79). The shot analysis performed with laser pistol indicated that the selective control strategy is to generate variations in the number of degrees of freedom of movement to hit the target (20).

Body has 244 degrees of freedom kinematic are needed to maintain the body part in a particular spatial orientation. Neilson (1993) shows that the CNS determines neural activity pattern of approximately 5 million motor fibers to control about 100-150 degrees of freedom (82). Considering 630 skeletal muscles, each degree of freedom is associated with 2.6 muscles (65). Degrees of freedom are redundant, motor task can accommodate other tasks at the same time. Flexibility accommodates the demands of human movement that arise in real world. Flexibility can be important feature of movement, more important than good control (49).

Motor control efficacy based on synergy has used biomechanical models to show that complex behaviors could be produced effectively with muscular synergies. The control system based on muscular synergies can be an effective for the CNS produce movement (19). The concept of muscle synergy resurfaced in neuroscience as a mechanism for neural control of movement, and represents muscle coordination patterns functional used to produce motor functions in healthy subjects (83). Synergism permeates movement by redundancy of the musculoskeletal system; muscle synergy uses the inherent motor solution, which selects the pattern to solve the driving task. Synergies can be characterized by the sharing of compensation and error (1,20), with a strategy sharing pattern. Synergism has been measured with EMG recordings (19) and quantify how elements covariate. Synergy is also observed in pursuit of stable sharing between patterns of output by elements of multi-element system (1).

Figure 5 - Controller delegating synergy



Source: Adapted from Latash (2008) (1)

Figure 5 describe the controller according to Latash (2008) that defines the overall task and organizes feedback loops to ensure stable running and the external conditions are already given, thereby delegating a synergism, i.e., the controller organizes elements in synergy ensuring the engine performance in an environment which undergoes changes (1). Elements act as muscles and are prone to natural variability, and to disruption other muscles. Coordinative structures are organized at all levels of the nervous system and establish constant impositions of degrees of freedom in the interaction through individual task system (84). Control of the movements is by hierarchical order for performance stability during movement (67,68,85).

Once Vaughan, Davis and O'Connor (1992) explain that during gait the challenge facing the CNS is to control simultaneously the actions of all these muscles, exemplifying that the ground reaction force can be the input to the movement control (86). In addition, Amadio (2002) complement by systematizing that the command system establishes a sequence related to the process of activation of nerve centers for movement control. This sequence of activation of the muscular patterns can be modified as a function of peripheral sensory system responses, joint control or even by the action of other receptors. The interaction between the CNS, peripheral nervous system and the musculoskeletal system defines the basis of functioning and command of movement, according to the principle of cause and effect (87).

Movement pattern is controlled by three peripheral sources of variation: mechanical or biomechanical, morphological and environmental (58). Therefore, motor system variability became the object of study of motor tasks. To evaluate the synergy, you can use the kinematics, kinetics, or EMG. The central organization of motor synergies is still debatable due to its complexity (68). However, many studies have only assessed the organization of movement's elements without associating them with the goal. A limitation to study the control of the central variables is due to the elusive nature, since the peripheral variables are less invasive (67).

There are several ways to combine muscles crossing a to perform a motor task (14,65,82). The set of solutions is much smaller than the total number of possible solutions. Thus, it is likely to experience a process of selection and or optimization. Studies based on the description and analysis of motor synergy seek for solutions to define the rules that organize motor solutions to perform task. The scientific paradigm that led to operational definition of synergy and creation approach to identify and quantify them (82,88), it is anchored in the search for answers to the classic problem of degrees of freedom, formulated by Bernstein (1,81,84).

3 MATERIALS AND METHODS

3.1 METHOD

This study is quantitative observational research (89). Dependent variable for the hypotheses is EMG signal. Independent variables are blocks, muscles, task (release arrow). Variables can be measured in different scale measures. In quantitative variable, zero value is not absence of variable (90).

3.2 DEFINITION OF OPERATIONAL TERMS

Anticipatory Postural Adjustment: pre-programmed response and learned for postural stabilization before the disturbance of voluntarily form (3), minimize risk of lose balance (2).

Archery Outdoor: This competition is held outdoor, field of proof should be flat without obstacles. Archery outdoor is part of Olympic and Pan American, archer uses recurve bow (91).

Clicker: device beeps when the bowstring of the archer is properly tensioned, clicker indicate when the desired tension has been achieved so that in sequence occurs shot the arrow (17). Clicker (draw length check) is a device attached to the bow which gives an audible indication when the arrow has been drawn to the desired predetermined draw length (42).

Coefficient of determination: common signal between two electrodes, is calculated by cross-correlation squared value (92).

Compensatory Postural Adjustment: mechanism that restoration the position of Center of Mass (COM) after a disturbance (2), this compensation phase stabilizes the body(4).

Coordination: behavior of two or more degrees of freedom in relation to each other to produce specific activities (59).

Cross-correlation: analyze evaluate how well a given signal is correlated with another signal across past, present, and future points in time (93).

Degrees of freedom: difficulty in clarifying the multiple simultaneous controls, regardless of parts of the body in movement (59).

Electrodes: connection between the biological tissue or cell and pre-amplifier input, in other words, junction between conducting electrolyte and metallic (94). Surface EMG uses surface electrodes to underlying muscles. Registration can inspect co-contraction, symmetry and asymmetry, flexion-relationship and other patterns of recruitment (95).

EMG: term that expresses the registration method of muscular electrical activity to identify movement patterns and parameters of control in nervous system (96). EMG is used to record the electrical activity (12,97) caused by potential axonal action (12), this area has biomechanical techniques that process the electrical signals for assessing electrical activity (92).

Filtering: signal processing for attenuates the signal and reduce interference signals by restricting the amplitude of the recorded frequency (12).

Latency: delay between a stimulus and a response (3).

Motor coordination: as the CNS selects the solution in numerous options of system effectors: the muscles, joints and limbs (80).

Normalization: quantify electrical activity transforming the absolute value in relative value using a reference value (98).

Rectification: process that involves elimination or inversion of phase or negative phase signal applied to EMG interference pattern (12,99).

Root Mean Square (RMS): indicates the amplitude of the EMG signal for continuous or discrete time (100). This method quantifies the EMG signal in which each value is raised to the square EMG, then sum and aggregate, and the root of the product is derived (95).

Synergy: Neural organization of signals sent up for elements (muscles, joints, effectors, etc.) of a multi-element system, ensuring stable performance of task (1). Synergy muscle group means produce additive muscular action with other muscles to create the smooth and coordinated movement (95).

3.3 ETHICAL ASPECTS

This research was approved by the Ethics Committee on Human Research of the College of Arts, Sciences and Humanities of the University of São Paulo registered in Presentation Certificate of Appreciation for Ethics (CAAE) 54077616.5.0000.5390. Participants signed Term of Consent and were instructed to clarify any doubts at any time, without receiving any cash value or benefit to participation, be exempt from the obligation to participate in this study. The subsequent presentation of partial and final report of this study was in accordance with Resolution CNS nº 466/12 – item XI.2.d.

3.4 PARTICIPANTS

Participants are 10 archers (4 men and 6 women) of Brazilian National Team (Table 2). Inclusion criteria to join in the Brazilian Team were: archers who had been training archery regularly, archers participate in regional, state and world championships in the last 12 months due to familiarization in outdoor competition. Score in the FITA must exceed 1000 points. Score FITA indicates archer performance level with international acceptance (7). FITA score is one of the best measures of archery level (7) because it is measured in the tournaments governed by the International Archery Association (7,17,22) due to objectivity and international acceptance. Criterion in the present study, the archery performance was averaged from all official scores for the year in which participants were tested (101). Exclusion criteria were: athletes with upper limb and trunk injuries in the last 12 months. All participants with injury at the time of testing or reported a previous injury history to their upper or lower limbs (102), participants having any signs or symptoms of peripheral neuropathy, compression syndrome of upper limbs, any history of traumatic injury of upper limb and history of rotator cuff injuries, injuries of wrist and elbow were excluded (40).

Table 2 - Characteristics of participants by Mean and Standard Deviation (SD)

Archer	Sex	Age (years)	Stature (m)	Body mass (kg)	Practice time (years)	Hand dominance
1	Male	32	1.91	81	21.0	Right-handed
2	Female	25	1.70	75	11.0	Right-handed
3	Female	19	1.55	68	2.0	Right-handed
4	Female	20	1.53	53	5.0	Left-handed
5	Male	16	1.83	90	4.0	Right-handed
6	Male	30	1.94	83	16.0	Right-handed
7	Female	17			3.0	Right-handed
8	Female	25	1.62	51	7.0	Right-handed
9	Male	17			1.5	Right-handed
10	Female	15	1.67	64	4.0	Right-handed
All archers	Male (n=4) Female (n=6)	21.60±5.12	1.72±0.13	70.63±11.63	7.45±5.13	Right-handed (n=9) Left-handed (n=1)

Participants were required to use their own bow and arrows for performance measurement purposes because their euipment is personalized (55).

3.5 PROCEDURE

3.5.1 Muscle electrical activity

For the analysis of electrical activity, we used the EMG (EMG System Brasil®) with 16 channels. Data was sampled at 2 kHz sampling frequency. The muscles were m. Flexor Digitorum (FLX), m. Extensor Digitorum (EXL), m. Biceps Brachii Long Head (BBL), m. Triceps Brachii (TB), m. Pectoralis Major Clavicular Head (PEM), m. Rectus Abdominis Anterior (RAT), m. Serratus Anterior pull string (SAPS), m. Lumbar Multifidus (MUL), m. Latissimus Dorsi (LDO) and m. Upper Trapezius (TRZ); and the muscles that stabilizes the bow: m. Serratus Anterior stabilizes the bow (SASB) and m. Posterior Deltoid (DEP).

3.5.1.1 Electrodes position

Electrode positioning on the skin respect the recommends the preparation of the skin according to Hermes et al. (1999) (100). Information about muscles with origin, insertion, action and electrode position in “APPENDIX B – MUSCLES ANALYZED: ORIGIN, INSERTION, ACTION AND ELECTRODE POSITION”.

3.5.2 Acceleration

Accelerometer (EMG System Brasil®) determined the beginning of the movement with increasing amplitude of the acceleration curve after the liberation of bowstring. Acceleration is captured in three orthogonal axes oriented with the planes of motion of the forearm.

3.5.3 Protocol

Brazilian National Team of archery was and the questions on the procedure were clarified, after this stage the athletes signed the Term of Consent. Then, the athletes were submitted to fixation of the electrodes in skin and of accelerometer on the wrist. Pre-test started with the accomplishment of the Maximal Voluntary Isometric Contraction (MVIC) of the evaluated muscles. The warm-up was 3 blocks of 6 arrows (18 arrows) and provided feedback for adjusting the cables for comfort during movement. EMG data collected during the shot and the archer performed two rounds of six blocks with six arrows in each block (36 arrows in each block, 72 arrows in total (38)), in other words, the competition the archer throws arrows for 12 blocks with a 20 minutes of interval after block 6. The distance target-archer are 70 meters, such as in the Olympic Games competition. The athlete did not fetch for the arrows as on the common training day, another person picked up the arrows in each block.

3.6 Signal Processing

Raw data (acceleration and EMG) were demeaned, filtered and ful-wave rectified. Zero mean raw data was filtered with 4th order low-pass Butterworth filter of 20 Hz to smooth, and to remove noise and possible distortions that occur in the capture and processing of the EMG signal (95, 96,99). Processed data was cropped within APA, CPA and M intervals with MATLAB 6.5 software. Temporal pattern were delimited due to the release time of the arrow (18) and latency of APA, CPA (3) and M. APA, CPA and M were determined by clicker, 500ms before and after clicker fall, other studies also used the device to determine the interval of interest (9–11,17). The following intervals were delineated in the APA (APA1, APA2, APA3, Pre-APA and Rest Time) and CPA (CPA1, CPA2 and CPA3) in each muscle. Each interval of APA and CPA has 100 ms. Clicker (draw length check) is a device attached to bow which gives an audible indication when arrow has been drawn to desired predetermined draw length (42).

Rectified EMG was normalized by activation of muscular electrical activity in the MVIC. Rectification involves taking the absolute value of raw signal that making all values in the signal positive (84). Then, it was calculated the Root Mean Square (RMS) from EMG signals in each interval of APA and CPA to interpret the behavior of muscular activity preserving signal potency indicating the magnitude of the signal in the MVIC (98). RMS improve the interpretation of the behavior of the muscular activity preserving the potential of signal indicating the magnitude of the signal of maximal voluntary contraction (98). Cross-correlation analyses evaluate how well a given signal is correlated with another signal across time (APA1, APA2, APA3, CPA1, CPA2 and CPA3) (93). The strength and polarity of this relationship is given by the correlation coefficient: the higher value the strong relation, while the sign indicates if variables "x" and "y" are increasing and decreasing together (positive correlation) or if one is increasing while the other is decreasing (negative correlation) (93). This study divided in motor and postural muscles in cross-correlation to describe those two motor actions, according to Levangie and Norkin (2011) (103). Postural muscles are almost continually active during standing to make small adjustments in muscle tension that are required to maintain body balance and counteract the effects of gravity. Nonpostural muscles are involved in producing a large range of motion of the bony components (103). Coefficient of determination of cross correlation was defined as the coativation index, because it identifoes the common signal between two EMG channels (92).

3.7 STUDY VARIABLES

The variables of this study were collected from the muscular electrical activity of the 12 muscles captured by the EMG for an analysis of temporal pattern of time-series EMG signals. Interval of interest was 500ms before and after clicker fall due to the release time of the arrow during the archers shot (18) and the latency time of APA (3), CPA and M. The total collection time for each arrow was 1 second, with intervals indicated in Table 3:

Table 3 – Intervals of temporal pattern

Data	Interval
APA1	50ms pre and 50 ms post clicker fall
APA2	50-150ms pre clicker fall
APA3	150-250ms pre clicker fall
Pre-APA	250-350ms pre clicker fall
Rest Time	400-500ms pre clicker fall
CPA1	50-150ms post clicker fall
CPA2	150-250ms post clicker fall
CPA3	250-350ms post clicker fall
M1	40-60ms post clicker fall
M2	60-80ms post clicker fall
M3	80-180ms post clicker fall

Abbreviation
APA: Anticipatory Postural Adjustment; CPA: Compensatory Postural Adjustment; M: Modulation

EMG data filtering processing attenuates and reduces interfering signals by restricting the amplitude of the recorded frequency. RMS quantifies the EMG signal at which each value is elevated to squared EMG; these are summed and aggregated so that the product root is derived. Normalization of the EMG data transformed the absolute values (MVIC value) into relative values by using the reference value. Electrical activity of the twelve muscles analyzed have as variables the intensity, co-activation index and cross-correlation index. Motor muscles are FLX, EXL, BBL, TB, PEM and DEP. Postural muscles are RAT, SAPS, MUL, LDO, TRZ and SASB. The strong correlation or highly correlated was considered the value higher than 0.9. Such APA can be about 100ms prior to activation of muscles that initiate the intended action (57). As APA latency is approximately 200ms (3), this study defined the intervals in APA (APA1, APA2, APA3, Pre-APA and Rest Time), CPA (CPA1, CPA2 and CPA3) and M (M1, M2 and M3).

3.8 DATA ANALYSIS

EMG time series of 12 muscles between 500ms before and after the clicker fall wree evaluated. Those time series were cropped into 5 APA epochs, 3 CPA epochs and 3 M epochs. Cross-correlation Analysis compared the time series of EMG.

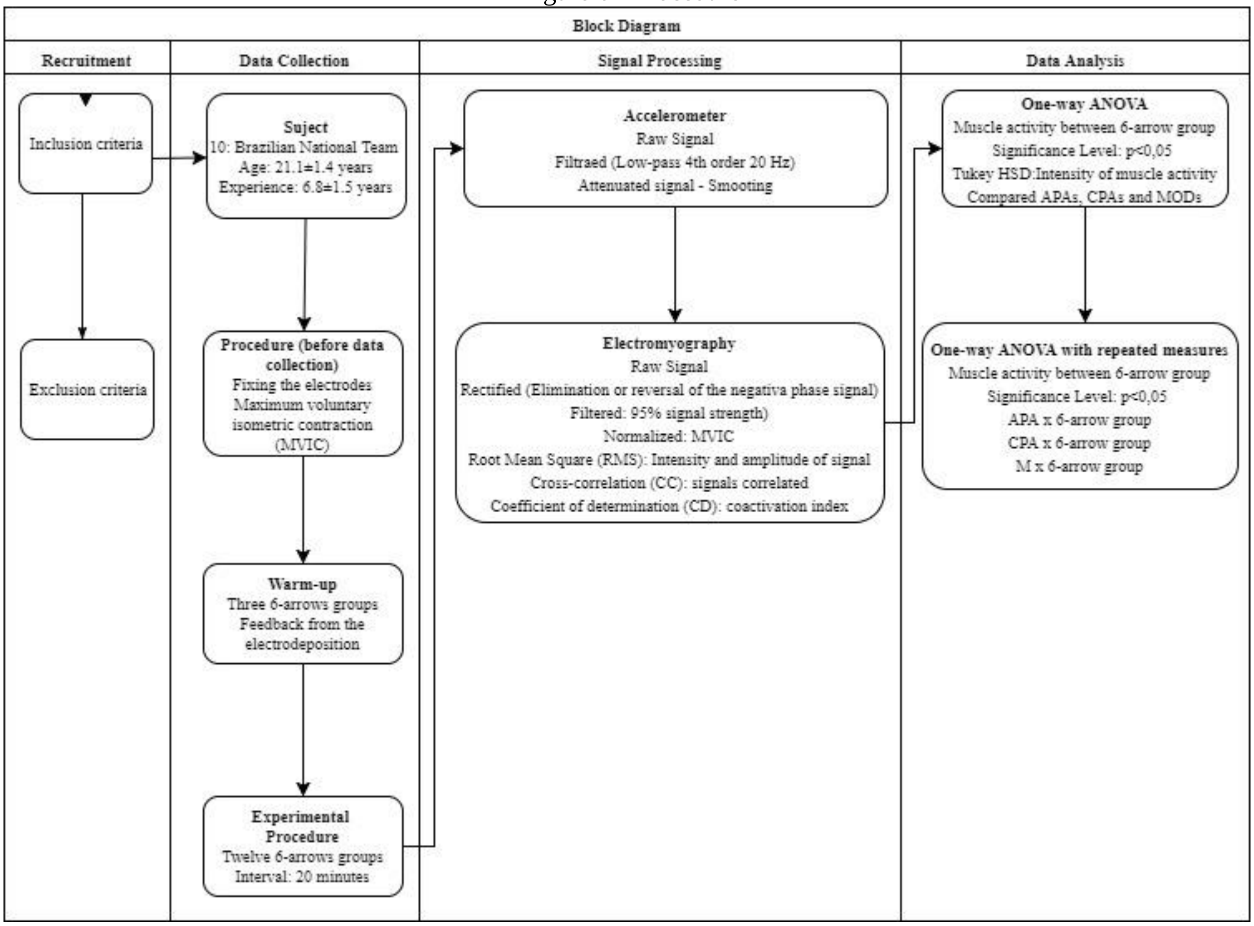
One-way analysis of variance (ANOVA) compared the RMS of each muscle across epochs APA (levels: APA1, APA2, APA3, Pre-APA and Rest Time), CPA (levels: CPA1, CPA2, CPA3) and M (M1, M2, M3). For post doc comparisons, it was used the Tukey Test post-hoc Honestly Significant Difference (HSD) (104, 105). The level of significance was $p<0,05$ (104). One-way ANOVA with repeated measures were performed: 1) across APA and 12 blocks of shots, 2) across CPA and 12 blocks and 3) across M and 12 blocks. One-way ANOVA with repeated measures is analysis of score in the same individuals on successive occasions.

Descriptive statistics (mean and standard deviation), ANOVA and Tukey test were performed in Origin 5.0. Graph were performed in Origin 2017.

3.9 BLOCK DIAGRAM

Block diagram shows the experimental procedure in each stage of the dissertation. A first part of the block diagram is experimental design of data collection with description of the participants (archers), procedure (before the data collection), warm-up and experimental procedure for data collection. After data collection occurs signal process of each equipment: accelerometers and EMG. Finally, data analysis with One-way ANOVA with Tukey and One-way ANOVA with repeated measures.

Figure 6 - Procedure



4 RESULTS

Results are divided into three parts: 1) muscle activity to mean and standard deviation of APA, CPA and M and results of One-way ANOVA and Tukey Test between APA, CPA and M and 2) One-way ANOVA with repeated measures were performed: between APA, CPA and M intervals and the blocks of shots, 3) cross correlation between motor and postural muscles. Tables 4 until 42 show APA and CPA and Modulation (M) of twelve muscles analyzed in this study. First part show muscle activity to mean and standard deviation of APA, CPA and M.

Table 4 - Mean and standard deviation (SD) of RMS of muscles during anticipatory postural adjustment (APA)

Muscles	APA1		APA2		APA3		Pre-APA		Rest Time	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
FXL	44.12	121.16	7.54	11.13	4.00	4.65	3.87	4.39	3.77	4.00
EXL	40.96	81.62	9.82	20.46	4.81	6.44	4.44	5.94	4.44	5.49
BBL	24.72	46.29	9.90	13.70	5.19	7.72	4.87	5.49	4.88	5.26
TB	73.50	169.25	12.92	28.67	10.81	33.72	10.17	23.09	10.03	27.50
PEM	40.87	82.04	16.02	38.05	6.35	27.35	6.55	32.62	7.89	37.99
RAT	18.75	59.93	9.15	44.68	7.67	41.79	6.54	37.18	5.89	34.31
SEPS	18.31	48.96	6.26	16.09	4.24	17.88	3.64	9.66	5.35	25.55
MUL	3.65	17.94	2.69	16.95	2.46	15.54	2.50	16.65	2.27	15.10
LDO	10.31	34.69	3.24	8.17	2.45	2.99	2.65	6.82	2.52	5.60
TRZ	35.21	91.61	10.79	24.88	9.03	21.81	9.02	22.35	8.41	14.52
SESB	8.40	19.04	5.13	13.71	3.28	18.93	3.19	20.34	3.58	22.66
DEP	25.89	59.00	11.56	26.44	12.3	35.04	11.36	31.46	10.40	27.44

Intervals for APA
APA1: 50ms pre and 50 ms post clicker; APA2: 50-150ms pre clicker; APA3: 150-250ms pre clicker; Pre-APA: 250-350ms pre clicker; Rest Time: 400-500ms pre clicker
Abbreviation of muscles
FXL, m. Flexor Digitorum Superficialis; EXL, m. Extensor Digitorum; BBL, m. Biceps Brachii Long Head; TB, m. Triceps Brachii; PEM, m. Pectoralis Major Clavicular Head; RAT, m. Rectus Abdominis Anterior; SEPS, m. Serratus Anterior pull string; MUL, m. Lumbar Multifidus; LDO, m. Latissimus Dorsi; TRZ, m. Upper Trapezius; SESB, m. Serratus Anterior stabilizes the bow; DEP, m. Posterior Deltoid.

Table 4 describes mean and standard deviation of electrical activity for intervals of APA. Muscle activation (RMS of EMG signal) across phases (APA1, APA2, APA3, Pre-APA and Rest Time) compared by One-way ANOVA. Electrical activity of m. Flexor Digitorum Superficialis ($F_{4,3199}$=67.1, $p<0.001$), m. Extensor Digitorum ($F_{4,3199}$=111.9, $p<0.001$), m. Biceps Brachii Long Head ($F_{4,3199}$=95.5, $p<0.001$), Triceps Brachii ($F_{4,3199}$=78.5, $p<0.001$), m. Pectoralis Major Clavicular Head ($F_{4,3199}$=60.5, $p<0.001$), m. Rectus Abdominis Anterior ($F_{4,3199}$=8.9, $p<0.001$), m. Serratus Anterior pull string ($F_{4,3199}$=31.9, $p<0.001$), m. Latissimus Dorsi ($F_{4,3199}$=27.3, p<0.01), m. Upper Trapezius ($F_{4,3199}$=42.3, p<0.001), m. Serratus Anterior stabilizes the bow ($F_{4,3199}$=8.4, p<0.001), m. Posterior Deltoid ($F_{4,3199}$=18.9, p<0.001) were affected by APA. Electrical activity of m. Lumbar Multifidus ($F_{4,3199}$=0.69, p=0.59) was not affected by APA.

Post hoc Tukey test showed that activation of m. Flexor Digitorum Superficialis, m. Extensor Digitorum, m. Biceps Brachii, m. Triceps Brachii, m. Pectoralis Major Clavicular Head, m. Rectus Abdominis Anterior, m. Serratus Anterior pull string, m. Latissimus Dorsi, m. Upper Trapezius and m. Posterior Deltoid were higher during APA1 than APA2 (p<0.001), APA1 than APA3 (p<0.001), APA1 than Pre-APA (p<0.001) and APA1 than Rest Time (p<0.001). Post hoc test showed that activation of m. Biceps Brachii was higher during APA2 than APA3 (p<0.05), APA2 than Pre-APA (p<0.001) and APA2 than Rest Time (p<0.001). Post hoc test showed that activation of m. Pectoralis Major Clavicular Head was higher during APA2 than APA3 (p<0.05), APA2 than Pre-APA (p<0.05) and APA2 than Rest Time (p<0.05). Post hoc test showed that activation of m. Lumbar Multifidus not change during APA (p>0.05). Post hoc test showed that activation of m. Serratus Anterior stabilizes the bow was higher during APA1 than APA2 (p<0.05), APA1 than APA3 (p<0.001), APA1 than Pre-APA (p<0.001), APA1 than Rest Time (p<0.001).

Table 5 - Mean and standard deviation (SD) of RMS of muscles during compensatory postural adjustment (CPA)

Muscles	CPA1		CPA2		CPA3	
	Mean	SD	Mean	SD	Mean	SD
m. FXL	44.53	107.23	46.22	156.70	45.18	154.84
m. EXL	18.61	59.38	5.69	14.53	4.93	9.78
m. BBL	13.99	29.18	9.44	23.20	9.16	22.99
m. TB	65.00	134.75	43.28	115.73	43.03	119.71
m. PEM	39.82	85.71	29.33	76.91	28.59	78.04
m. RAT	28.77	81.94	26.13	83.24	24.65	80.90
m. SEPS	19.22	57.20	6.20	21.08	5.07	16.84
m. MUL	5.24	23.67	3.83	17.71	3.67	17.47
m. LDO	14.76	50.15	9.74	36.41	9.49	37.46
m. TRZ	39.66	111.93	24.60	76.83	23.08	75.19
m. SESB	5.63	17.88	4.21	16.62	4.06	16.76
m. DEP	32.83	65.19	27.16	57.63	25.39	56.11

Intervals for CPA

CPA1: 50-150ms post clicker; CPA2: 150-250ms post clicker; CPA3: 250-350ms post clicker

Abbreviation of muscles

FXL, m. Flexor Digitorum Superficialis; EXL, m. Extensor Digitorum; BBL, m. Biceps Brachii Long Head; TB, m. Triceps Brachii; PEM, m. Pectoralis Major Clavicular Head; RAT, m. Rectus Abdominis Anterior; SEPS, m. Serratus Anterior pull string; MUL, m. Lumbar Multifidus; LDO, m. Latissimus Dorsi; TRZ, m. Upper Trapezius; SESB, m. Serratus Anterior stabilizes the bow; DEP, m. Posterior Deltoid.

Table 5 show the mean and standard deviation of electrical activity for intervals of CPA.

RMS EMG across phases (CPA1, CPA2 and CPA3) was compared using One-way ANOVA. Activation of m. Extensor Digitorum ($F_{2,1919}$=29.5 p<0.001), m. Biceps Brachii Long Head ($F_{2,1919}$=7.3 p<0.001), m. Triceps Brachii ($F_{2,1919}$=6.6 p<0.001), m. Pectoralis Major Clavicular Head ($F_{2,1919}$=3.9, p=0.02), m. Serratus Anterior pull string ($F_{2,1919}$=29.6, p<0.001), m. Latissimus Dorsi ($F_{2,1919}$=3.2, p=0.03), m. Upper Trapezius ($F_{2,1919}$=6.6, p<0.001) were affected by CPA. Activation of m. Flexor Digitorum Superficialis ($F_{2,1919}$=0.0, p=0.97), m. Rectus Abdominis Anterior ($F_{2,1919}$=0.4, p=0.66), m. Lumbar Multifidus ($F_{2,1919}$=1.2, p=0.59), m. Serratus Anterior stabilizes the bow ($F_{2,1919}$=1.6, p=0.19) and m. Posterior Deltoid ($F_{2,1919}$=2.7, p=0.06) were not affected by CPA.

Post hoc Tukey test showed that activation of m. Extensor Digitorum and m. Serratus Anterior pull string were higher during CPA1 than CPA2 (p<0.001) and CPA1 than CPA3 (p<0.001). Post hoc test showed that activation of m. Biceps Brachii, m. Triceps Brachii and m. Upper Trapezius were higher during CPA1 than CPA2 (p<0.05) and CPA1 than CPA3 (p<0.05). Post hoc test showed that activation of m. Pectoralis Major Clavicular Head was higher during CPA1 than CPA3 (p<0.05). Post hoc test showed that activation of m. Flexor Digitorum Superficialis, m. Rectus Abdominis Anterior, m. Lumbar Multifidus, m. Latissimus Dorsi, m. Serratus Anterior stabilizes the bow, m. Posterior Deltoid not change during CPA (p>0.05).

Table 6 - Mean and standard deviation (SD) of RMS of muscles during modulation (M)

Muscles	M1		M2		M3	
	Mean	SD	Mean	SD	Mean	SD
m. FXL	54.33	169.31	38.37	118.00	40.55	11.73
m. EXL	29.04	73.07	22.39	69.81	13.67	50.42
m. BBL	20.65	42.31	15.27	32.90	11.70	26.26
m. TB	86.61	213.44	79.49	191.31	53.78	100.28
m. PEM	41.22	88.98	40.80	90.59	36.41	82.47
m. RAT	22.31	69.75	24.67	76.79	30.01	86.74
m. SEPS	21.18	62.26	21.18	67.37	16.05	50.74
m. MUL	3.96	23.06	4.56	26.51	5.08	22.01
m. LDO	13.15	48.90	14.61	57.14	13.53	45.28
m. TRZ	45.99	129.46	44.09	126.41	34.56	102.27
m. SESB	6.70	18.12	5.83	18.20	5.12	17.38
m. DEP	27.45	63.78	27.91	61.26	32.53	67.11

Intervals for M

M1: 40-60ms post clicker; M2: 60-80ms post clicker; M3: 80-180ms post clicker

Abbreviation of muscles

FXL, m. Flexor Digitorum Superficialis; EXL, m. Extensor Digitorum; BBL, m. Biceps Brachii Long Head; TB, m. Triceps Brachii; PEM, m. Pectoralis Major Clavicular Head; RAT, m. Rectus Abdominis Anterior; SEPS, m. Serratus Anterior pull string; MUL, m. Lumbar Multifidus; LDO, m. Latissimus Dorsi; TRZ, m. Upper Trapezius; SESB, m. Serratus Anterior stabilizes the bow; DEP, m. Posterior Deltoid.

Table 6 described the result of mean and standard deviation of electrical activity for intervals of M. Muscle activation (RMS of EMG signal) across phases (M1, M2 and M3) was compared using One-way ANOVA. Activation of m. Flexor Digitorum Superficialis ($F_{2,1919}$=2.5, p=0.07), m. Extensor Digitorum was affected by phase ($F_{2,1919}$=8.9, p<0.001), m. Biceps Brachii Long Head ($F_{2,1919}$=10.9, p<0.001), m. Triceps Brachii ($F_{2,1919}$=6.2, p<0.001) were affected by M phase. Activation of m. Pectoralis Major Clavicular Head ($F_{2,1919}$=0.5, p=0.55), m. Rectus Abdominis Anterior ($F_{2,1919}$=1.6, p=0.19), m. Serratus Anterior pull string ($F_{2,1919}$=1.5, p<0.21), m. Lumbar Multifidus ($F_{2,1919}$=0.3, p=0.70), m. Latissimus Dorsi ($F_{2,1919}$=0.1, p=0.86), Activation of m. Upper Trapezius ($F_{2,1919}$=1.6, p=0.18), m. Serratus Anterior stabilizes the bow ($F_{2,1919}$=1.2, p=0.28), m. Posterior Deltoid ($F_{2,1919}$=1.2, p=0.29) were not affected by M phase.

Post hoc analysis by Tukey test showed that activation of m. Extensor Digitorum was higher during M1 than M3 (p<0.001) and M2 than M3 (p<0.05). Post hoc test showed that activation of m. Biceps Brachii was higher during M1 than M2 (p<0.05) and M1 than M3 (p<0.001). Post hoc test showed that activation of m. Triceps Brachii was higher during M1 than M3 (p<0.05) and M2 than M3 (p<0.05). Post hoc showed that activation of m. Flexor Digitorum Superficialis, m. Pectoralis Major Clavicular Head, m. Rectus Abdominis Anterior, m. Serratus Anterior pull string, m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius, m. Serratus Anterior stabilizes the bow, m. Posterior Deltoid not change during M phase (p>0.05).

The second part of the results show One-way ANOVA with repeated measures performed in: 1) between APA and the 12 blocks of 6-arrows, 2) between CPA 12 blocks of 6-arrows and 3) between M and the 12 blocks of 6-arrows. All results of Table 7 until Table 42 were mean and standard deviation of RMS of each muscle.

Tables 7, 8 and 9 describe m. Flexor Digitorum Superficialis RMS across APA (APA1, APA2, APA3, Pre-APA and Rest Time), CPA (CPA1, CPA2 and CPA3), M (M1, M2 and M3) and blocks of 6 arrows using One-way ANOVA with repeated measures. For APA, m. Flexor Digitorum Superficialis was affected by blocks in APA1 ($F_{11,639}$=2.0, p<0.05) and APA2 ($F_{11,639}$=2.1, p<0.05), it was not affected by blocks in APA3 ($F_{11,639}$=0.6, p=0.74), Pre-APA ($F_{11,639}$=0.4, p=0.91) and Rest Time ($F_{11,639}$=0.6, p=0.74). For CPA, m. Flexor Digitorum Superficialis was not affected by blocks in CPA1 ($F_{11,639}$=0.6, p=0.77), CPA2 ($F_{11,639}$=0.8, p=0.54) and CPA3 ($F_{11,639}$=0.9, p=0.47). For M, m. Flexor Digitorum Superficialis was not affected by blocks in M1 ($F_{11,639}$=1.3, p=0.17), M2 ($F_{11,639}$=1.2, p=0.26) and M3 ($F_{11,639}$=0.4, p=0.91).

Tables 10, 11 and 12 describe m. Extensor Digitorum RMS across APA (APA1, APA2, APA3, Pre-APA and Rest Time), CPA (CPA1, CPA2 and CPA3), M (M1, M2 and M3) and blocks of 6 arrows using One-way ANOVA with repeated measures. For APA, m. Extensor Digitorum was not affected by blocks in any APA ($F_{11,639} \leq 0.8$, $p \geq 0.60$), Pre-APA ($F_{11,639}=0.5$, $p=0.89$) and Rest Time ($F_{11,639}=0.7$, $p=0.69$). For CPA, m. Extensor Digitorum was not affected by blocks in any CPA ($F_{11,639} \leq 1.3$, $p \geq 0.20$). For M, m. Extensor Digitorum was not affected by blocks in any M ($F_{11,639} \leq 1.3$, $p \geq 0.18$).

Table 7 - Mean and standard deviation (SD) of RMS of m. Flexor Digitorum Superficialis during anticipatory postural adjustment (APA) and the 12 blocks of 6-arrows

Blocks	APA1		APA2		APA3		Pre-APA		Rest Time	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	46.21	100.78	8.53	10.89	3.41	2.66	3.13	2.36	2.92	2.18
2	53.87	112.97	12.18	20.23	5.16	11.46	4.76	9.99	4.68	8.98
3	73.39	207.21	10.11	20.54	3.42	2.69	4.04	4.18	3.81	3.82
4	83.85	161.34	10.73	13.47	3.63	3.63	3.95	4.30	3.15	2.53
5	85.25	209.68	7.90	11.34	3.97	3.08	3.81	3.67	3.99	3.62
6	34.30	98.97	6.79	8.96	4.59	4.39	3.90	3.34	3.99	3.68
7	33.92	103.83	6.84	7.68	4.40	4.03	4.06	3.37	3.76	3.12
8	16.53	61.65	5.42	6.76	3.87	3.91	3.76	3.86	3.58	3.52
9	24.54	64.05	6.37	6.92	4.48	5.61	4.35	4.96	3.90	3.58
10	30.92	77.92	5.49	4.32	3.71	2.38	3.51	2.84	4.19	3.58
11	44.40	106.69	6.63	6.94	3.55	2.75	3.87	3.54	3.85	3.28
12	19.19	45.65	5.03	3.93	3.83	3.00	3.49	2.68	3.50	3.22

Table 8 - Mean and standard deviation (SD) of RMS of m. Flexor Digitorum Superficialis during compensatory postural adjustment (CPA) and the 12 blocks of 6-arrows

Blocks	CPA1		CPA2		CPA3	
	Mean	SD	Mean	SD	Mean	SD
1	44.50	105.76	63.83	195.32	63.70	197.31
2	36.43	95.51	29.89	117.82	28.38	118.22
3	62.65	161.62	20.40	69.40	17.00	58.71
4	40.46	101.83	7.19	22.40	6.47	21.55
5	62.60	137.60	35.08	149.56	33.45	145.69
6	39.84	102.04	59.55	193.83	59.29	191.18
7	49.10	112.14	66.40	181.85	64.96	179.22
8	33.98	97.58	47.42	175.85	45.72	171.76
9	27.04	60.60	37.63	127.10	37.55	124.68
10	49.34	100.56	75.21	185.77	76.07	188.07
11	60.91	114.60	60.22	181.26	57.78	175.37
12	32.77	86.14	37.84	146.89	37.06	145.01

Table 9 - Mean and standard deviation (SD) of RMS of m. Flexor Digitorum Superficialis during modulation (M) and the 12 blocks of 6-arrows

Blocks	M1		M2		M3	
	Mean	SD	Mean	SD	Mean	SD
1	43.35	115.14	30.07	71.42	47.39	132.14
2	48.36	122.20	31.58	85.00	33.68	100.52
3	91.59	274.89	75.50	223.29	44.09	121.88
4	86.99	227.62	56.42	156.07	18.68	44.68
5	112.55	280.28	64.30	158.16	40.52	123.72
6	41.60	148.55	26.53	88.45	41.99	129.57
7	49.54	169.96	32.77	108.35	49.97	130.92
8	21.34	95.29	15.74	59.11	39.41	129.12
9	34.02	97.04	26.67	68.68	26.28	78.53
10	47.76	136.70	37.84	115.81	51.40	114.66
11	66.33	172.46	53.27	135.81	57.21	131.69
12	26.77	81.23	22.61	69.98	34.13	107.59

Table 10 - Mean and standard deviation (SD) of RMS of m. Extensor Digitorum during anticipatory postural adjustment (APA) and the 12 blocks of 6-arrows

Blocks	APA1		APA2		APA3		Pre-APA		Rest Time	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	25.63	56.47	8.36	11.01	5.80	11.06	5.76	11.27	4.49	7.25
2	49.19	96.48	7.40	10.90	3.82	4.37	4.30	7.94	4.16	6.26
3	45.46	73.06	9.64	15.41	3.83	2.73	3.94	4.54	3.38	3.05
4	48.20	105.82	7.03	5.72	3.73	2.78	3.62	2.70	3.40	2.51
5	23.79	44.12	8.63	14.09	4.51	6.45	4.24	5.55	4.76	6.46
6	45.62	74.65	11.27	15.07	5.94	7.33	5.10	5.98	5.28	5.57
7	53.29	104.74	10.57	10.16	5.42	7.89	4.10	4.92	4.00	3.91
8	42.11	102.87	14.63	56.74	4.89	4.79	4.10	3.47	4.27	4.49
9	41.33	78.56	10.88	10.59	5.25	6.18	4.81	5.86	5.44	6.62
10	28.14	46.62	8.04	8.43	4.66	4.78	4.39	4.13	5.09	5.86
11	52.26	88.04	11.40	14.97	5.22	8.39	4.64	5.89	4.39	5.69
12	37.77	76.55	9.17	14.23	4.08	3.91	4.07	4.08	42.30	5.81

Table 11 - Mean and standard deviation (SD) of RMS of m. Extensor Digitorum during compensatory postural adjustment (CPA) and the 12 blocks of 6-arrows

Blocks	CPA1		CPA2		CPA3	
	Mean	SD	Mean	SD	Mean	SD
1	13.65	31.13	4.37	6.96	3.93	6.37
2	19.16	45.31	4.14	5.75	3.81	5.21
3	14.68	23.83	4.89	7.05	4.47	6.06
4	10.02	13.05	3.84	4.95	3.51	4.53
5	8.97	10.05	4.82	7.05	4.62	6.81
6	33.28	115.37	7.59	18.00	6.24	10.48
7	38.19	108.96	8.75	23.94	7.04	16.44
8	22.71	72.81	9.41	33.80	7.23	20.47
9	15.33	48.18	5.21	6.53	4.80	5.95
10	9.86	9.61	5.01	6.80	4.45	6.03
11	18.93	40.99	4.80	6.00	4.40	5.71
12	15.19	40.42	4.50	5.03	4.06	4.67

Table 12 - Mean and standard deviation (SD) of RMS of m. Extensor Digitorum during modulation (M) and the 12 blocks of 6-arrows

Blocks	M1		M2		M3	
	Mean	SD	Mean	SD	Mean	SD
1	23.01	69.35	16.15	42.53	9.65	17.40
2	34.94	62.54	26.37	65.14	11.90	33.04
3	26.08	35.10	17.45	22.06	10.08	22.35
4	21.76	38.45	12.98	19.10	6.11	6.00
5	16.60	28.92	11.30	14.56	6.52	6.84
6	40.58	87.93	35.91	105.46	26.57	109.41
7	51.39	140.45	48.37	147.80	29.43	82.76
8	21.65	41.87	19.79	54.74	20.45	77.73
9	28.33	95.30	19.84	70.40	10.09	24.75
10	17.12	22.36	11.12	10.92	7.87	8.96
11	36.22	69.79	26.35	63.27	11.91	26.05
12	28.93	73.90	19.98	57.64	10.14	25.11

Table 13 - Mean and standard deviation (SD) of RMS of m. Biceps Brachii Long Head during anticipatory postural adjustment (APA) and the 12 blocks of 6-arrows

Blocks	APA1		APA2		APA3		Pre-APA		Rest Time	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	32.76	64.01	12.96	19.49	5.62	7.82	5.13	6.73	4.53	5.88
2	10.07	13.11	7.49	13.26	3.71	3.45	4.41	7.05	3.44	3.82
3	15.52	28.69	7.71	8.99	4.49	4.56	3.78	5.10	3.97	4.30
4	18.31	31.21	7.25	8.03	3.72	2.93	3.71	2.84	3.84	3.63
5	30.34	45.07	10.94	15.36	8.11	20.61	5.13	6.01	5.66	5.44
6	21.43	34.61	10.70	13.40	5.75	7.01	6.11	6.96	6.16	7.08
7	33.01	70.57	12.46	19.15	5.07	4.93	4.56	3.90	4.54	4.36
8	24.72	42.62	9.15	12.52	5.33	5.36	5.79	6.80	5.02	5.82
9	39.26	69.16	11.60	14.90	5.33	6.26	5.22	5.18	5.19	4.93
10	20.57	30.67	8.77	9.45	5.31	5.03	4.91	4.31	5.48	5.59
11	20.56	28.20	9.78	12.27	4.75	4.59	4.14	3.88	4.97	5.44
12	24.81	42.13	8.73	10.13	4.85	4.88	5.05	5.17	5.35	5.28

Table 14 - Mean and standard deviation (SD) of RMS of m. Biceps Brachii Long Head during compensatory postural adjustment (CPA) and the 12 blocks of 6-arrows

Blocks	CPA1		CPA2		CPA3	
	Mean	SD	Mean	SD	Mean	SD
1	23.60	59.42	11.18	32.52	9.71	24.23
2	6.87	6.99	5.46	7.91	5.16	7.16
3	10.70	17.99	7.62	13.06	7.48	12.92
4	10.44	14.48	7.84	10.96	7.60	10.72
5	13.02	15.28	10.41	15.30	10.14	15.22
6	10.33	12.20	13.63	34.99	14.05	37.45
7	15.76	33.95	13.65	46.55	13.74	48.90
8	13.74	24.83	8.08	11.09	7.96	11.42
9	22.72	49.20	11.23	23.31	10.68	21.91
10	13.01	18.37	8.27	12.86	8.01	13.21
11	11.66	13.37	8.01	12.04	7.77	12.06
12	13.04	19.38	6.35	12.00	6.24	12.79

Table 15 - Mean and standard deviation (SD) of RMS of m. Biceps Brachii Long Head during modulation (M) and the 12 blocks of 6-arrows

Blocks	M1		M2		M3	
	Mean	SD	Mean	SD	Mean	SD
1	32.17	72.88	24.55	49.71	19.28	60.39
2	7.95	8.12	6.96	6.32	6.52	8.10
3	13.65	20.32	11.12	19.62	9.62	16.79
4	15.95	25.72	11.70	16.29	8.92	12.37
5	20.42	27.48	12.90	12.88	11.35	15.35
6	15.23	20.66	9.74	10.73	9.82	13.67
7	20.07	38.38	14.80	25.23	14.09	35.39
8	20.65	36.57	15.44	31.56	11.51	20.09
9	38.51	80.82	29.78	74.11	16.62	33.23
10	17.30	23.73	14.47	22.81	11.39	15.66
11	17.15	21.08	12.27	13.70	10.22	12.65
12	24.06	45.24	15.83	27.32	8.82	10.02

Table 13, 14 and 15 describe m. Biceps Brachii Long Head RMS across APA (APA1, APA2, APA3, Pre-APA and Rest Time), CPA (CPA1, CPA2 and CPA3), M (M1, M2 and M3) and 12 blocks of 6 arrows were compared using One-way ANOVA with repeated measures. For APA, m. Biceps Brachii Long Head was not affected by blocks in any APA ($F_{11,639} \leq 1.7$, $p \geq 0.06$), Pre-APA ($F_{11,639}=0.9$, $p=0.48$) and Rest Time ($F_{11,639}=1.1$, $p=0.28$). For CPA, m. Biceps Brachii Long Head was not affected by blocks in any CPA ($F_{11,639} \leq 1.7$, $p \geq 0.06$). For M, m. Biceps Brachii Long Head was affected by blocks in M1 ($F_{11,639}=2.0$, $p<0.05$) and M2 ($F_{11,639}=2.0$, $p<0.05$), but it was not affected by blocks in M3 ($F_{11,639}=1.0$, $p=0.43$).

Table 16 - Mean and standard deviation (SD) of RMS of m. Triceps Brachii during anticipatory postural adjustment (APA) and the 12 blocks of 6-arrows

Blocks	APA1		APA2		APA3		Pre-APA		Rest Time	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	30.42	64.34	9.46	8.63	7.61	7.83	7.21	6.80	7.50	10.71
2	32.38	78.21	16.06	44.69	7.20	7.77	7.00	7.70	8.26	10.21
3	47.36	148.85	9.89	15.80	8.84	13.26	8.76	12.36	7.92	10.48
4	92.75	213.91	25.45	76.22	30.34	105.76	25.67	68.73	5.27	5.55
5	92.52	210.99	10.97	12.76	8.52	9.81	9.53	12.70	5.85	6.82
6	73.21	183.62	12.19	16.30	9.78	10.89	9.44	10.26	7.17	11.72
7	86.38	188.08	14.83	26.27	14.10	39.25	12.54	25.00	20.56	44.11
8	98.77	195.84	13.02	16.69	7.99	8.77	8.28	9.10	9.68	12.01
9	70.12	165.89	11.81	16.03	9.91	11.93	9.64	13.41	18.56	73.08
10	76.05	162.09	10.54	11.39	9.31	11.16	7.65	8.12	9.89	11.47
11	94.73	169.82	11.64	14.61	8.20	9.52	8.23	8.31	8.47	9.58
12	80.63	171.53	9.68	11.19	8.15	11.81	8.40	11.36	8.04	11.43

Table 17 - Mean and standard deviation (SD) of RMS of m. Triceps Brachii during compensatory postural adjustment (CPA) and the 12 blocks of 6-arrows

Blocks	CPA1		CPA2		CPA3	
	Mean	SD	Mean	SD	Mean	SD
1	59.10	131.44	3.38	5.63	2.62	3.81
2	79.55	149.87	5.58	8.22	3.95	4.99
3	39.08	96.42	4.78	10.17	4.47	10.76
4	38.35	95.17	48.11	121.28	49.21	126.18
5	26.81	51.99	48.45	114.17	47.94	112.51
6	64.00	139.06	40.95	104.73	39.81	109.45
7	104.21	190.90	70.30	141.63	70.01	149.56
8	72.38	143.82	33.53	84.09	31.29	82.59
9	72.30	150.73	39.08	104.14	38.67	106.76
10	66.16	145.74	36.75	112.49	35.97	115.85
11	73.81	136.12	36.97	112.49	36.32	115.10
12	53.23	113.77	18.06	70.83	17.55	70.57

Table 18 - Mean and standard deviation (SD) of RMS of m. Triceps Brachii during modulation (M) and the 12 blocks of 6-arrows

Blocks	M1		M2		M3	
	Mean	SD	Mean	SD	Mean	SD
1	23.55	42.73	18.82	31.72	25.51	55.42
2	19.46	47.93	15.97	34.98	20.74	43.38
3	65.95	191.34	81.54	204.35	72.49	128.69
4	109.69	266.98	104.23	249.08	86.72	139.27
5	111.41	264.16	108.96	255.61	64.47	117.53
6	82.80	216.22	74.91	189.64	48.55	90.91
7	105.26	238.65	93.22	201.53	50.76	86.70
8	124.64	268.84	108.07	229.79	55.01	115.69
9	73.16	189.09	65.26	154.77	45.51	85.83
10	98.85	215.15	89.18	194.22	50.22	89.17
11	121.85	225.86	107.93	202.53	71.91	106.46
12	95.05	221.94	84.09	185.40	58.64	101.58

Table 16, 17 and 18 describe the m. Triceps Brachii RMS across APA (APA1, APA2, APA3, Pre-APA and Rest Time), CPA (CPA1, CPA2 and CPA3), M (M1, M2 and M3) and 12 blocks of 6 arrows using One-way ANOVA with repeated measures. For APA, activation of m. Triceps Brachii was affected by blocks in APA3 ($F_{11,639}$=1.8, p<0.05) and Pre-APA ($F_{11,639}$=2.5, p<0.05), but it was not affected by blocks in any other APA ($F_{11,639}$≤1.2, p≥0.26) and Rest Time ($F_{11,639}$=1.7, p=0.06). For CPA, m. Triceps Brachii was affected by blocks in CPA2 ($F_{11,639}$=2.4, p<0.05) and CPA3 ($F_{11,639}$=2.3, p<0.05), but it was not affected by blocks in CPA1 ($F_{11,639}$=1.2, p=0.23). For M, m. Triceps Brachii was affected by blocks in M3 ($F_{11,639}$=1.8, p<0.05), but it was not affected by blocks in M1 ($F_{11,639}$=1.4, p=0.15) and M2 ($F_{11,639}$=1.4, p=0.13).

Table 19 - Mean and standard deviation (SD) of RMS of m. Pectoralis Major Clavicular Head during anticipatory postural adjustment (APA) and the 12 blocks of 6-arrows

Blocks	APA1		APA2		APA3		Pre-APA		Rest Time	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	38.37	79.06	9.60	17.44	1.51	1.30	1.46	1.32	1.46	1.54
2	47.92	107.16	31.48	79.49	14.75	46.39	21.75	73.40	17.31	59.67
3	30.32	69.93	12.80	27.13	9.54	37.84	4.66	18.44	8.54	40.16
4	35.23	69.53	9.63	15.42	1.82	2.73	1.38	2.02	1.68	2.94
5	46.96	85.22	13.92	23.61	3.01	6.45	2.75	5.18	11.65	53.94
6	51.39	98.03	17.36	38.41	9.71	39.29	14.88	67.2	16.41	64.27
7	29.84	59.80	17.85	41.67	10.06	37.10	5.86	17.71	4.40	14.69
8	36.25	67.68	14.20	26.67	4.38	14.87	5.61	21.71	3.75	15.88
9	48.13	95.64	15.32	34.46	5.73	17.81	6.75	24.51	11.56	49.30
10	42.44	76.64	13.87	27.15	1.98	2.41	1.56	1.83	4.82	25.20
11	31.20	59.26	12.90	30.07	3.78	10.96	4.56	13.69	2.39	7.04
12	51.86	103.78	24.67	53.66	11.34	44.61	8.71	33.64	12.52	43.77

Table 20 - Mean and standard deviation (SD) of RMS of m. Pectoralis Major Clavicular Head during compensatory postural adjustment (CPA) and the 12 blocks of 6-arrows

Blocks	CPA1		CPA2		CPA3	
	Mean	SD	Mean	SD	Mean	SD
1	33.62	81.94	19.61	62.43	19.45	61.83
2	34.93	80.24	27.20	78.51	28.68	84.67
3	26.60	64.62	18.93	54.89	19.50	57.21
4	46.65	97.18	38.58	86.89	36.11	84.09
5	45.38	105.39	24.85	71.72	23.98	75.28
6	51.62	104.37	44.13	107.94	43.29	108.7
7	35.19	85.73	25.42	68.97	24.16	67.85
8	31.60	68.80	31.27	77.88	32.13	81.56
9	44.15	101.85	27.01	61.91	26.78	63.16
10	42.32	81.56	29.35	71.02	25.99	64.82
11	32.60	61.01	23.94	71.25	22.93	73.46
12	51.30	82.94	39.96	95.17	38.92	99.91

Table 21 - Mean and standard deviation (SD) of RMS of m. Pectoralis Major Clavicular Head during modulation (M) and the 12 blocks of 6-arrows

Blocks	M1		M2		M3	
	Mean	SD	Mean	SD	Mean	SD
1	36.50	88.68	38.32	94.23	29.10	75.80
2	51.35	120.45	46.12	107.37	25.75	61.04
3	30.23	79.88	30.69	74.50	22.40	57.14
4	38.20	79.81	44.34	98.63	47.67	99.13
5	42.20	81.12	41.86	90.05	41.41	103.75
6	55.06	115.33	55.30	119.80	49.34	99.96
7	26.41	53.59	29.51	65.57	35.32	90.10
8	34.56	74.01	30.81	71.75	29.34	66.37
9	53.17	116.23	52.29	122.89	35.21	87.79
10	37.74	66.40	35.84	62.95	41.94	90.01
11	35.29	73.32	33.95	70.23	30.45	57.66
12	53.71	96.76	50.15	86.84	46.38	80.10

Table 19, 20 and 21 describe m. Pectoralis Major Clavicular Head RMS across APA

(APA1, APA2, APA3, Pre-APA and Rest Time), CPA (CPA1, CPA2 and CPA3), M (M1, M2 and M3) and 12 blocks of 6 arrows compared using One-way ANOVA with repeated measures. For APA, m. Pectoralis Major Clavicular Head was not affected by blocks in any APA ($F_{11,639}$=1.3, p=0.18), Pre-APA ($F_{11,639}$=1.7, p=0.05) and Rest Time ($F_{11,639}$=1.2, p=0.28). For CPA, m. Pectoralis Major Clavicular Head was not affected by blocks in any CPA ($F_{11,639}$=0.5, p=0.85). For M, m. Pectoralis Major Clavicular Head was not affected by blocks in any M phase ($F_{11,639}$=0.5, p=0.78).

Table 22 - Mean and standard deviation (SD) of RMS of m. Rectus Abdominis Anterior during anticipatory postural adjustment (APA) and the 12 blocks of 6-arrows

Blocks	APA1		APA2		APA3		Pre-APA		Rest Time	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	22.52	72.95	10.35	61.6	9.98	61.81	9.43	57.74	1.68	3.70
2	16.54	47.46	2.45	3.86	1.20	1.45	1.10	1.50	1.10	1.44
3	20.12	59.32	3.33	5.68	2.61	6.10	1.75	4.67	2.66	6.39
4	13.92	53.29	4.00	10.62	5.01	19.78	1.95	3.73	3.24	7.64
5	7.73	17.14	5.50	20.00	2.65	4.92	2.67	4.77	2.38	4.53
6	2.90	4.43	2.58	4.67	1.77	3.40	1.97	3.46	2.37	5.00
7	21.81	60.27	5.95	22.32	3.41	4.88	3.67	5.42	3.09	5.34
8	24.27	77.67	8.85	32.86	13.30	61.16	13.26	49.14	13.30	49.48
9	35.11	86.55	20.01	66.42	22.44	74.09	14.96	66.71	16.26	83.45
10	23.76	65.29	10.29	43.75	6.23	18.82	6.70	32.36	3.77	13.21
11	25.05	75.01	31.20	102.16	18.92	76.43	16.54	65.63	16.95	58.32
12	8.26	24.80	2.55	4.10	1.28	1.81	1.54	2.70	1.83	3.47

Table 23 - Mean and standard deviation (SD) of RMS of m. Rectus Abdominis Anterior during compensatory postural adjustment (CPA) and the 12 blocks of 6-arrows

Blocks	CPA1		CPA2		CPA3	
	Mean	SD	Mean	SD	Mean	SD
1	40.12	86.82	36.89	87.75	31.74	75.23
2	28.99	86.37	26.10	90.31	22.92	78.75
3	28.47	119.01	10.22	50.46	10.51	53.29
4	17.91	59.99	6.46	20.12	6.25	20.93
5	14.81	45.20	21.48	75.45	22.71	81.65
6	4.98	9.85	31.45	106.80	33.80	115.59
7	47.07	101.83	22.00	61.12	18.53	55.45
8	20.33	55.35	23.45	89.20	22.93	89.70
9	56.33	124.31	44.18	111.55	41.27	106.00
10	40.49	102.58	32.01	91.82	27.79	79.64
11	22.59	45.55	34.40	91.34	33.33	91.73
12	17.62	54.31	18.51	69.00	18.44	71.13

Table 24 - Mean and standard deviation (SD) of RMS of m. Rectus Abdominis Anterior during modulation (M) and the 12 blocks of 6-arrows

Blocks	M1		M2		M3	
	Mean	SD	Mean	SD	Mean	SD
1	25.35	64.07	25.33	58.05	44.61	105.10
2	23.02	72.75	24.09	81.30	30.76	99.74
3	31.27	101.00	30.35	110.41	23.59	110.83
4	19.11	67.76	20.94	71.54	15.14	49.85
5	10.35	31.04	13.98	45.90	14.97	43.22
6	2.48	3.66	2.82	5.16	8.00	20.92
7	30.76	90.17	40.80	106.22	45.89	99.46
8	24.03	76.76	19.41	61.37	21.05	59.97
9	42.72	98.68	48.32	113.38	57.81	131.17
10	26.10	70.13	34.06	87.39	44.75	115.48
11	17.42	47.71	15.39	37.36	27.86	58.60
12	13.38	45.89	17.62	63.47	18.63	53.22

Tables 22, 23 and 24 describe m. Rectus Abdominis Anterior RMS across APA (APA1, APA2, APA3, Pre-APA and Rest Time), CPA (CPA1, CPA2 and CPA3), M (M1, M2 and M3) and 12 blocks of 6 arrows using One-way ANOVA with repeated measures. For APA, m. Rectus Abdominis Anterior was affected by blocks in APA2 ($F_{11,639}$=2.0, $p<0.05$), but it was not affected by blocks in APA1 ($F_{11,639}$=1.2, p=0.24), APA3 ($F_{11,639}$=1.6, p=0.07), Pre-APA ($F_{11,639}$=1.2, p=0.22) and Rest Time ($F_{11,639}$=1.6, p=0.07). For CPA, m. Rectus Abdominis Anterior was affected by blocks in CPA1 ($F_{11,639}$=1.9, $p<0.05$), but it was not affected by blocks in CPA2 ($F_{11,639}$=0.9, p=0.53) and CPA3 ($F_{11,639}$=0.8, p=0.62). For M, m. Rectus Abdominis Anterior was not affected by blocks in M1 ($F_{11,639}$=1.2, p=0.22), M2 ($F_{11,639}$=1.4, p=0.13) and M3 ($F_{11,639}$=1.8, p=0.05).

Table 25 - Mean and standard deviation (SD) of RMS of m. Serratus Anterior pull string during anticipatory postural adjustment (APA) and the 12 blocks of 6-arrows

Blocks	APA1		APA2		APA3		Pre-APA		Rest Time	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	14.33	37.50	3.63	4.20	2.81	2.94	2.78	3.32	2.10	2.30
2	11.68	27.26	6.13	21.91	3.23	8.16	2.04	2.03	2.17	2.08
3	13.71	53.35	5.20	9.36	3.54	5.11	2.88	3.37	3.07	4.43
4	22.55	62.14	4.44	4.62	2.85	3.33	2.41	3.31	3.65	5.22
5	16.45	55.26	6.17	10.19	3.61	4.48	3.45	3.70	6.66	24.76
6	22.11	56.62	5.92	8.07	3.00	2.63	2.97	3.05	7.81	34.36
7	10.84	26.62	4.41	4.86	3.01	3.24	3.46	4.56	2.40	2.96
8	17.22	38.92	6.85	16.23	3.01	4.03	3.49	4.57	2.82	3.34
9	8.11	17.97	4.46	4.57	4.10	4.75	3.41	3.82	3.17	3.81
10	25.73	61.53	7.70	14.27	3.27	3.26	3.03	3.16	2.70	2.83
11	28.57	64.69	7.96	21.58	10.25	53.31	3.53	5.35	2.40	2.05
12	28.18	58.56	12.32	37.42	8.40	28.78	10.00	30.69	25.56	74.91

Table 26 - Mean and standard deviation (SD) of RMS of m. Serratus Anterior pull string during compensatory postural adjustment (CPA) and the 12 blocks of 6-arrows

Blocks	CPA1		CPA2		CPA3	
	Mean	SD	Mean	SD	Mean	SD
1	25.76	67.20	9.43	24.00	6.72	15.08
2	17.78	63.96	5.19	18.65	3.76	11.13
3	13.66	38.95	8.20	28.81	6.44	22.37
4	20.12	58.60	6.36	25.80	5.27	20.30
5	14.79	57.00	8.40	27.23	7.26	24.16
6	18.43	51.59	3.45	4.39	3.00	3.48
7	13.11	38.79	3.38	4.97	2.96	3.72
8	21.65	57.23	10.00	35.60	7.52	24.63
9	16.69	57.50	4.80	7.16	3.99	4.65
10	24.76	65.55	8.10	29.69	7.45	30.64
11	26.56	75.94	3.68	4.11	3.26	3.43
12	15.68	43.64	3.68	4.03	3.35	3.42

Table 27 - Mean and standard deviation (SD) of RMS of m. Serratus Anterior pull string during modulation (M) and the 12 blocks of 6-arrows

Blocks	M1		M2		M3	
	Mean	SD	Mean	SD	Mean	SD
1	26.24	82.74	27.30	83.57	21.89	57.89
2	18.35	50.72	20.28	67.20	14.79	60.48
3	9.66	27.46	7.63	14.30	14.35	45.73
4	26.66	76.71	24.98	73.30	16.27	50.59
5	18.53	72.03	16.05	61.11	13.36	50.95
6	28.04	79.09	24.82	75.64	12.41	34.07
7	13.77	34.41	14.15	42.26	10.80	34.65
8	19.80	53.05	21.13	65.01	19.81	58.30
9	10.27	25.62	14.12	46.27	16.08	56.27
10	24.27	64.37	25.47	72.76	20.85	58.86
11	33.40	87.72	36.39	106.73	19.71	57.38
12	23.76	49.88	19.51	53.41	11.26	36.58

Table 25, 26 and 27 describe m. Serratus Anterior pull string RMS across APA (APA1, APA2, APA3, Pre-APA and Rest Time), CPA (CPA1, CPA2 and CPA3), M (M1, M2 and M3), and 12 blocks of 6 arrows compared using One-way ANOVA with repeated measures. For APA, m. Serratus Anterior pull string was affected by blocks in Pre-APA ($F_{11,639}$=2.4, p<0.05), Rest Time ($F_{11,639}$=3.7, p<0.001), but it was not affected by blocks in any APA ($F_{11,639}$≤0.9, p≥0.32). For CPA, m. Serratus Anterior pull string was not affected by blocks in any CPA ($F_{11,639}$≤0.7, p≥0.67). For M, m. Serratus Anterior pull string was not affected by blocks in M1 ($F_{11,639}$=0.7, p=0.71), M2 ($F_{11,639}$=0.6, p=0.79) and M3 ($F_{11,639}$=0.3, p=0.98).

Table 28 - Mean and standard deviation (SD) of RMS of m. Lumbar Multifidus during anticipatory postural adjustment (APA) and the 12 blocks of 6-arrows

Blocks	APA1		APA2		APA3		Pre-APA		Rest Time	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	7.90	38.15	6.65	37.66	6.52	37.45	6.57	37.52	6.47	37.44
2	0.86	0.86	0.66	0.53	0.65	0.54	0.69	0.57	0.67	0.58
3	5.50	13.07	2.04	3.25	1.68	2.67	1.68	2.70	1.64	2.12
4	2.09	4.67	1.38	3.13	1.53	3.59	1.52	3.72	1.27	2.70
5	13.63	38.40	12.27	40.99	11.94	35.74	12.08	40.68	9.80	33.17
6	8.43	24.95	5.68	16.41	3.65	11.01	4.13	14.02	3.81	12.55
7	1.22	1.79	0.79	1.28	0.90	1.55	0.70	0.63	0.76	1.15
8	0.98	1.01	0.61	0.45	0.61	0.43	0.62	0.45	0.69	0.49
9	0.79	0.65	0.67	0.48	0.61	0.45	0.63	0.52	0.61	0.40
10	0.99	0.90	0.66	0.53	0.60	0.47	0.61	0.44	0.65	0.51
11	1.24	1.25	0.60	0.42	0.63	0.50	0.62	0.54	0.62	0.58
12	1.15	2.04	0.81	0.99	0.70	0.48	0.67	0.46	0.64	0.46

Table 29 - Mean and standard deviation (SD) of RMS of m. Lumbar Multifidus during compensatory postural adjustment (CPA) and the 12 blocks of 6-arrows

Blocks	CPA1		CPA2		CPA3	
	Mean	SD	Mean	SD	Mean	SD
1	11.64	54.83	8.23	38.37	8.29	38.51
2	1.06	1.31	0.87	0.89	0.85	0.87
3	9.48	22.20	6.35	17.78	6.16	17.94
4	1.73	3.07	1.51	2.21	1.52	2.34
5	15.66	38.53	10.50	25.05	9.41	22.85
6	10.57	28.33	9.33	29.42	9.53	30.98
7	1.75	4.59	1.17	1.50	1.11	1.24
8	1.53	1.94	1.15	1.07	1.08	0.90
9	1.05	1.06	0.87	0.70	0.86	0.70
10	1.35	1.50	1.02	0.81	0.94	0.73
11	7.00	25.96	4.72	18.51	3.92	15.22
12	1.46	1.72	1.09	0.80	1.00	0.74

Table 30 - Mean and standard deviation (SD) of RMS of m. Lumbar Multifidus during modulation (M) and the 12 blocks of 6-arrows

Blocks	M1		M2		M3	
	Mean	SD	Mean	SD	Mean	SD
1	13.81	67.09	15.68	77.25	8.90	42.62
2	1.04	1.87	1.09	2.07	0.99	0.93
3	6.76	14.48	7.58	17.21	9.55	22.77
4	1.76	3.27	1.78	3.70	1.63	2.65
5	10.04	29.32	9.93	24.99	16.44	40.99
6	7.40	21.00	10.11	30.95	10.14	27.03
7	1.29	1.53	1.56	3.24	1.70	4.71
8	1.16	1.28	1.31	1.40	1.52	2.08
9	0.88	0.83	1.01	1.00	1.02	1.05
10	0.92	0.74	1.09	1.08	1.41	1.58
11	1.94	3.37	2.82	7.49	7.85	30.16
12	1.06	0.85	1.19	1.12	1.50	1.81

Table 28, 29 and 30 describe m. Lumbar Multifidus RMS across APA (APA1, APA2, APA3, Pre-APA and Rest Time), CPA (CPA1, CPA2 and CPA3), M (M1, M2 and M3), and 12 blocks of 6 arrows compared using One-way ANOVA with repeated measures. For APA, m. Lumbar Multifidus was affected by blocks in all APA ($F_{11,639}\geq 2.4$, $p<0.05$), Pre-APA ($F_{11,639}=2.3$, $p<0.05$) and Rest Time ($F_{11,639}=2.0$, $p<0.05$). For CPA, m. Lumbar Multifidus was affected by blocks in all CPA ($F_{11,639}\geq 2.3$, $p<0.05$). For M, m. Lumbar Multifidus was affected by blocks in M1 ($F_{11,639}=2.0$, $p<0.05$), M2 ($F_{11,639}=1.9$, $p<0.05$) and M3 ($F_{11,639}=2.9$, $p<0.001$).

Table 31 - Mean and standard deviation (SD) of RMS of m. Latissimus Dorsi during anticipatory postural adjustment (APA) and the 12 blocks of 6-arrows

Blocks	APA1		APA2		APA3		Pre-APA		Rest Time	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	6.80	13.59	2.43	2.26	2.12	1.81	2.38	2.03	2.16	1.99
2	7.58	28.35	2.43	1.87	2.21	1.68	2.28	1.66	2.19	1.42
3	16.37	38.08	2.23	1.76	2.30	1.72	2.22	1.77	2.20	1.61
4	10.77	27.86	2.56	1.85	2.62	2.01	2.44	1.91	2.28	1.47
5	11.63	33.90	3.05	4.05	3.29	4.10	3.40	5.25	3.19	5.06
6	4.78	10.49	2.52	2.20	2.07	1.44	2.32	1.74	2.14	1.60
7	17.56	59.04	7.49	24.19	3.30	7.53	5.31	21.49	4.19	15.52
8	4.54	13.97	2.24	1.38	2.12	1.56	2.16	1.53	2.12	1.38
9	16.69	59.00	3.87	7.26	2.20	1.45	2.20	1.52	2.07	1.48
10	11.84	31.13	3.79	5.51	2.61	2.11	2.45	2.10	2.42	2.15
11	9.04	31.27	2.78	4.40	2.25	1.51	2.29	1.43	2.01	1.35
12	6.52	25.41	2.87	2.69	2.32	1.86	2.19	1.35	3.16	8.30

Table 32 - Mean and standard deviation (SD) of RMS of m. Latissimus Dorsi during compensatory postural adjustment (CPA) and the 12 blocks of 6-arrows

Blocks	CPA1		CPA2		CPA3	
	Mean	SD	Mean	SD	Mean	SD
1	18.87	48.17	12.82	43.96	12.1	43.49
2	15.39	62.79	15.02	51.77	15.14	54.43
3	42.10	99.71	21.68	59.46	21.11	61.69
4	15.72	41.53	9.08	31.98	8.58	30.72
5	18.44	54.31	16.97	50.15	17.97	54.29
6	3.98	9.45	3.75	15.01	3.80	16.43
7	13.11	48.45	7.23	26.45	6.90	25.88
8	2.36	2.55	1.72	1.56	1.66	1.56
9	19.98	64.29	13.09	44.51	13.56	46.72
10	14.17	32.92	10.58	38.84	9.76	39.99
11	8.66	32.86	3.79	9.89	3.06	6.62
12	10.31	42.54	4.88	17.74	4.01	14.53

Table 33 - Mean and standard deviation (SD) of RMS of m. Latissimus Dorsi during modulation (M) and the 12 blocks of 6-arrows

Muscles	M1		M2		M3	
	Mean	SD	Mean	SD	Mean	SD
1	11.05	26.31	14.56	37.60	19.27	51.29
2	16.03	70.64	20.21	97.07	12.79	45.75
3	37.26	93.22	48.70	121.46	36.50	86.24
4	15.31	43.75	15.92	46.18	14.17	39.54
5	19.99	74.49	19.75	70.41	15.56	42.05
6	4.43	13.42	4.30	13.38	3.40	6.72
7	12.96	45.98	12.76	45.39	11.86	46.47
8	3.30	7.54	2.53	3.58	2.07	1.73
9	16.98	62.62	19.01	69.46	18.81	58.11
10	11.98	31.14	11.51	29.18	13.99	33.95
11	8.55	29.54	7.20	23.85	7.98	32.79
12	6.18	21.57	7.17	27.21	10.53	44.40

Table 31, 32 and 33 describe m. Latissimus Dorsi RMS across APA (APA1, APA2, APA3, Pre-APA and Rest Time), CPA (CPA1, CPA2 and CPA3), M (M1, M2 and M3), and 12 blocks of 6 arrows compared using One-way ANOVA with repeated measures. For APA, m. Latissimus Dorsi was affected by blocks in APA2 ($F_{11,639}=1.8$, $p<0.05$), but it was not affected by blocks in APA1 ($F_{11,639}=0.9$, $p=0.47$), APA3 ($F_{11,639}=1.1$, $p=0.33$), Pre-APA ($F_{11,639}=1.0$, $p=0.44$) and Rest Time ($F_{11,639}=0.7$, $p=0.66$). For CPA, m. Latissimus Dorsi was affected by blocks in CPA1 ($F_{11,639}=2.0$, $p<0.05$), but it was not affected by blocks in CPA2 ($F_{11,639}=1.4$, $p=0.15$) and CPA3 ($F_{11,639}=1.4$, $p=0.15$). For M, m. Latissimus Dorsi was affected by blocks in M2 ($F_{11,639}=2.1$, $p=0.01$) and M3 ($F_{11,639}=1.9$, $p=0.03$), but it was not affected by blocks in M1 ($F_{11,639}=1.6$, $p=0.07$).

Table 34 - Mean and standard deviation (SD) of RMS of m. Upper Trapezius during anticipatory postural adjustment (APA) and the 12 blocks of 6-arrows

Blocks	APA1		APA2		APA3		Pre-APA		Rest Time	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	51.42	133.03	8.42	10.01	6.72	8.53	5.84	5.17	5.61	5.31
2	31.24	78.64	12.66	45.35	5.94	6.84	4.75	5.11	5.42	4.91
3	26.21	61.72	9.55	13.13	8.77	14.50	8.93	14.79	8.94	14.22
4	73.58	146.25	21.57	53.41	7.70	11.85	9.18	14.07	10.77	18.03
5	61.03	138.81	11.11	13.78	8.50	11.25	10.95	16.38	9.01	11.31
6	57.38	119.19	11.50	14.90	10.34	17.28	10.29	15.27	10.04	14.49
7	24.26	62.72	7.87	8.21	10.24	25.04	15.49	60.51	12.25	31.61
8	15.25	36.40	7.97	10.53	7.74	10.77	6.19	7.22	8.72	12.41
9	19.39	60.68	9.02	11.52	10.37	12.46	9.52	12.51	7.41	9.63
10	16.40	39.98	8.20	9.82	8.95	10.65	8.07	10.08	8.53	10.32
11	17.82	43.33	7.42	11.62	7.07	9.08	7.69	10.26	6.98	11.89
12	32.99	64.64	15.57	40.24	15.56	61.05	10.81	25.94	6.89	7.27

Table 35 - Mean and standard deviation (SD) of RMS of m. Upper Trapezius during compensatory postural adjustment (CPA) and the 12 blocks of 6-arrows

Blocks	CPA1		CPA2		CPA3	
	Mean	SD	Mean	SD	Mean	SD
1	54.81	135.89	29.67	85.23	27.39	83.50
2	50.37	141.92	29.78	87.22	25.75	75.67
3	29.98	71.59	22.96	78.48	22.04	83.04
4	83.42	190.79	53.55	134.57	49.09	130.31
5	53.78	133.17	36.06	101.95	34.38	100.54
6	52.39	115.13	27.48	73.57	24.91	70.06
7	34.39	104.73	19.45	53.57	17.26	49.42
8	13.46	40.60	18.30	57.21	19.23	62.12
9	28.33	93.19	21.84	71.40	22.57	76.71
10	21.58	67.57	11.67	43.01	11.99	47.08
11	21.13	65.58	7.44	19.92	6.13	11.97
12	37.58	98.89	20.97	62.56	19.48	56.84

Table 36 - Mean and standard deviation (SD) of RMS of m. Upper Trapezius during modulation (M) and the 12 blocks of 6-arrows

Blocks	M1		M2		M3	
	Mean	SD	Mean	SD	Mean	SD
1	60.51	157.32	61.84	158.77	46.55	122.68
2	40.53	120.98	42.74	122.34	50.17	145.48
3	34.16	92.12	30.80	75.93	26.51	65.43
4	90.46	202.82	85.19	199.14	76.61	181.85
5	74.59	178.91	65.38	161.44	44.90	118.62
6	74.98	166.23	65.43	145.33	41.35	97.36
7	36.04	111.23	35.36	115.97	31.00	95.74
8	18.36	62.91	16.15	61.00	11.34	27.68
9	30.01	106.86	30.46	107.11	26.10	78.97
10	25.46	76.54	29.32	97.37	16.67	49.43
11	23.27	70.25	24.63	84.39	17.96	55.34
12	48.04	114.94	45.27	114.73	31.30	90.49

Table 34, 35 and 36 described m. Upper Trapezius RMS signal across APA (APA1, APA2, APA3, Pre-APA and Rest Time), CPA (CPA1, CPA2 and CPA3), M (M1, M2 and M3), and 12 blocks of 6 arrows compared using One-way ANOVA with repeated measures. For APA, m. Upper Trapezius was affected by blocks in APA1 ($F_{11,639}$=2.6, p<0.05), but it was not affected by blocks in APA2 ($F_{11,639}$=1.4, p=0.14), APA3 ($F_{11,639}$=0.7, p=0.73), Pre-APA ($F_{11,639}$=0.8, p=0.54) and Rest Time ($F_{11,639}$=1.0, p=0.38). For CPA, m. Upper Trapezius was not affected by blocks in any CPA ($F_{11,639}$≤1.6, p≥0.08). For M., m. Upper Trapezius was not affected by blocks in any M phase ($F_{11,639}$≤1.7, p≥0.05).

Table 37 - Mean and standard deviation (SD) of RMS of m. Serratus Anterior stabilizes the bow during anticipatory postural adjustment (APA) and the 12 blocks of 6-arrows

Blocks	APA1		APA2		APA3		Pre-APA		Rest Time	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	6.20	8.05	3.29	4.29	1.77	2.11	2.02	2.67	1.67	1.98
2	4.80	5.45	3.21	3.10	1.56	1.68	1.86	1.80	1.58	1.62
3	4.65	4.96	3.81	5.05	1.63	1.60	1.51	1.57	1.58	1.60
4	5.83	6.20	3.77	3.75	2.12	2.03	1.74	1.71	1.61	1.47
5	23.62	44.56	18.08	45.28	21.12	66.17	20.50	71.67	26.93	78.72
6	9.76	19.7	5.32	6.97	1.97	1.87	1.82	1.79	1.91	1.77
7	11.60	34.37	4.25	5.15	1.95	2.04	1.85	1.89	1.52	1.48
8	6.41	5.91	3.89	3.73	1.43	1.32	1.56	1.45	1.65	1.83
9	6.37	5.96	4.14	4.49	1.91	1.86	1.64	1.53	1.55	1.69
10	7.05	6.98	4.83	4.97	2.02	1.97	1.76	1.69	1.53	1.53
11	8.57	17.78	4.26	4.75	2.09	1.94	1.87	2.03	1.92	1.85
12	6.17	6.11	3.64	3.39	1.35	1.26	1.56	1.52	1.61	1.53

Table 38 - Mean and standard deviation (SD) of RMS of m. Serratus Anterior stabilizes the bow during compensatory postural adjustment (CPA) and the 12 blocks of 6-arrows

Blocks	CPA1		CPA2		CPA3	
	Mean	SD	Mean	SD	Mean	SD
1	3.72	5.64	3.00	3.51	2.85	3.28
2	2.87	3.30	2.19	1.92	2.15	1.86
3	3.08	4.24	2.44	2.07	2.35	2.00
4	3.05	2.69	2.39	2.03	2.31	1.96
5	24.95	59.3	20.72	57.38	20.26	58.12
6	5.88	5.99	3.65	3.42	3.35	3.10
7	4.71	4.51	2.96	2.30	2.83	2.12
8	3.50	2.92	2.90	2.36	2.86	2.38
9	4.31	3.35	2.85	2.06	2.74	2.02
10	4.58	3.87	3.05	2.44	2.93	2.41
11	3.57	3.52	2.98	2.56	2.89	2.52
12	4.54	10.81	2.57	2.75	2.35	2.17

Table 39 - Mean and standard deviation (SD) of RMS of m. Serratus Anterior stabilizes the bow during modulation (M) and the 12 blocks of 6-arrows

Blocks	M1		M2		M3	
	Mean	SD	Mean	SD	Mean	SD
1	5.23	8.53	4.12	6.52	3.37	4.93
2	3.80	6.15	3.06	3.98	2.51	2.57
3	3.31	3.89	3.05	4.27	2.94	4.03
4	4.03	4.58	3.17	3.49	2.77	2.34
5	26.05	58.50	25.51	60.35	23.21	58.07
6	7.21	9.09	5.99	6.93	5.31	5.43
7	6.94	8.74	5.45	6.12	3.87	3.51
8	4.67	5.18	3.65	3.58	3.09	2.59
9	5.07	5.02	4.54	3.85	3.88	3.08
10	5.24	4.71	4.56	4.08	4.22	3.73
11	5.06	7.88	3.60	4.36	3.22	3.04
12	4.76	4.89	4.39	7.60	4.20	10.96

Table 37, 38 and 39 describe m. Serratus Anterior stabilizes the bow RMS across APA

(APA1, APA2, APA3, Pre-APA and Rest Time), CPA (CPA1, CPA2 and CPA3), M (M1, M2 and M3) and 12 blocks of 6 arrows compared using One-way ANOVA with repeated measures. For APA, m. Serratus Anterior stabilizes the bow was affected by blocks in any APA ($F_{11,639} \geq 3.8$, $p<0.001$), Pre-APA ($F_{11,639}=3.6$, $p<0.001$) and Rest Time ($F_{11,639}=5.5$, $p<0.001$). For CPA, m. Serratus Anterior stabilizes the bow was affected by blocks in any CPA ($F_{11,639} \geq 4.8$, $p<0.001$). For M, m. Serratus Anterior stabilizes the bow was affected by blocks in any M phase ($F_{11,639} \geq 5.7$, $p<0.001$).

Table 40 - Mean and Standard Deviation (SD) of RMS of m. Posterior Deltoid during anticipatory postural adjustment (APA) and the 12 blocks of 6-arrows

Blocks	APA1		APA2		APA3		Pre-APA		Rest Time	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	23.31	52.44	10.45	30.59	9.82	27.52	11.72	40.98	7.84	14.28
2	28.95	64.47	14.09	37.90	19.20	55.27	11.79	25.15	10.70	25.09
3	31.43	84.57	12.47	28.64	9.91	24.12	8.50	21.36	12.76	38.69
4	23.22	61.58	13.29	32.21	15.27	53.14	11.51	32.50	10.82	34.30
5	23.74	56.88	8.82	13.09	7.63	10.20	8.49	13.71	10.94	33.92
6	29.14	57.09	11.37	15.35	10.97	23.60	7.94	9.65	8.05	10.67
7	27.75	61.88	10.91	17.57	9.96	17.12	9.61	13.31	7.93	10.43
8	22.71	51.34	15.10	37.36	20.11	59.67	16.67	53.09	12.58	32.76
9	19.55	42.15	15.74	39.15	14.17	31.59	16.26	44.55	12.90	26.01
10	25.06	56.52	10.51	19.84	10.39	24.54	10.73	28.20	12.37	34.42
11	30.46	63.86	7.62	9.41	6.81	8.55	7.34	9.49	6.66	9.09
12	27.13	59.09	8.27	10.80	13.31	38.94	14.66	40.70	11.70	38.58

Table 41 - Mean and standard deviation (SD) of RMS of m. Posterior Deltoid during compensatory postural adjustment (CPA) and the 12 blocks of 6-arrows

Blocks	CPA1		CPA2		CPA3	
	Mean	SD	Mean	SD	Mean	SD
1	22.46	54.30	19.76	43.14	18.29	39.29
2	32.87	61.31	24.72	50.33	23.49	48.63
3	35.14	70.03	40.69	86.89	38.97	88.45
4	39.19	75.80	30.77	55.55	27.55	51.62
5	31.22	59.21	26.55	51.55	24.59	50.60
6	28.13	45.40	24.86	41.58	24.02	41.45
7	25.38	55.22	25.15	55.14	24.17	54.52
8	42.73	76.60	37.70	75.86	34.46	73.31
9	38.24	86.64	29.74	58.67	28.01	57.89
10	35.05	57.04	26.11	55.48	25.03	56.13
11	34.17	68.49	19.96	45.05	18.10	41.21
12	30.25	65.13	21.96	63.06	19.98	59.24

Table 42 - Mean and standard deviation (SD) of RMS of m. Posterior Deltoid during modulation (M) and the 12 blocks of 6-arrows

Blocks	M1		M2		M3	
	Mean	SD	Mean	SD	Mean	SD
1	21.29	46.73	18.91	38.97	21.93	59.61
2	38.46	96.26	35.78	81.14	27.52	51.53
3	29.50	84.03	29.13	76.42	36.60	71.13
4	29.44	80.31	35.30	82.59	38.82	74.98
5	22.19	49.03	21.20	45.01	33.19	62.84
6	29.58	53.25	28.87	50.98	25.91	44.45
7	22.60	57.77	22.25	55.94	26.17	56.26
8	25.39	55.84	26.27	51.29	46.19	85.80
9	21.72	42.72	25.82	45.75	39.24	92.69
10	32.22	68.94	31.32	63.62	33.43	54.33
11	35.13	70.36	38.77	80.99	31.51	64.24
12	24.31	52.38	23.44	52.29	30.31	71.95

Table 40, 41 and 42 describe m. Posterior Deltoid RMS across APA (APA1, APA2, APA3, Pre-APA and Rest Time), CPA (CPA1, CPA2 and CPA3), M (M1, M2 and M3), and 12 blocks of 6 arrows compared using One-way ANOVA with repeated measures. For APA, m. Posterior Deltoid was not affected by blocks in any APA ($F_{11,639} \leq 0.5$, $p \geq 0.86$), Pre-APA ($F_{11,639}=0.5$, $p=0.86$) and Rest Time ($F_{11,639}=0.3$, $p=0.97$). For CPA, m. Posterior Deltoid was not affected by blocks in any CPA ($F_{11,639} \leq 0.6$, $p \geq 0.97$). For M, m. Posterior Deltoid was not affected by blocks in any M phase ($F_{11,639} \leq 0.5$, $p \geq 0.84$).

In Cross-correlation, it was separated as motor muscles are m. Flexor Digitorum Superficialis, m. Extensor Digitorum, Biceps Brachii Long Head, m. Triceps Brachii, m. Pectoralis Major Clavicular Head and m. Posterior Deltoid. Postural muscles are m. Rectus Abdominis Anterior, m. Serratus Anterior pull string, m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius and m. Serratus Anterior stabilizes the bow. The strong correlation or highly correlated was considered the value higher than 0.9.

Table 43 - Cross-correlation (CC) and coefficient of determination (CD) between muscles (CC | CD)

		Motor muscles					
		m. EXL	m. BBL	m. TB	m. PEM	m. DEL	
Motor muscles	m. FLX	0.76 | 0.57	0.88 | 0.77	0.97 | 0.93	0.97 | 0.94	0.95 | 0.91	
	m. EXL	-	0.96 | 0.92	0.89 | 0.79	0.86 | 0.74	0.78 | 0.60	
	m. BBL	-	-	0.95 | 0.91	0.96 | 0.91	0.91 | 0.83	
	m. TB	-	-	-	0.99 | 0.98	0.96 | 0.92	
	m. PEM	-	-	-	-	0.98 | 0.95	
		Postural muscles					
		m. SEPS	m. MUL	m. LDO	m. TPZ	m. SESB	
Postural muscles	m. RAT	0.87 | 0.76	0.96 | 0.93	0.99 | 0.97	0.97 | 0.94	0.89 | 0.78	
	m. SEPS	-	0.91 | 0.82	0.93 | 0.86	0.96 | 0.93	0.93 | 0.87	
	m. MUL	-	-	0.95 | 0.91	0.96 | 0.92	0.95 | 0.91	
	m. LDO	-	-	-	0.99 | 0.98	0.90 | 0.80	
	m. TPZ	-	-	-	-	0.94 | 0.88	
		Postural muscles					
		m. RAT	m. SEPS	m. MUL	m. LDO	m. TPZ	m. SESB
Motor muscles	m. FLX	0.97 | 0.95	0.85 | 0.73	0.90 | 0.80	0.97 | 0.95	0.96 | 0.91	0.85 | 0.72
	m. EXL	0.72 | 0.51	0.93 | 0.86	0.76 | 0.57	0.79 | 0.62	0.86 | 0.74	0.89 | 0.79
	m. BBL	0.87 | 0.75	0.95 | 0.91	0.90 | 0.81	0.90 | 0.81	0.95 | 0.90	0.98 | 0.95
	m. TB	0.95 | 0.89	0.95 | 0.91	0.92 | 0.84	0.98 | 0.95	0.99 | 0.98	0.92 | 0.84
	m. PEM	0.97 | 0.94	0.95 | 0.89	0.95 | 0.89	0.99 | 0.97	0.99 | 0.99	0.94 | 0.88
	m. DEL	0.99 | 0.98	0.91 | 0.83	0.99 | 0.97	0.98 | 0.97	0.98 | 0.97	0.94 | 0.88

Muscles
FXL, m. Flexor Digitorum Superficialis; EXL, m. Extensor Digitorum; BBL, m. Biceps Brachii Long Head; TB, m. Triceps Brachii; PEM, m. Pectoralis Major Clavicular Head; RAT, m. Rectus Abdominis Anterior; SEPS, m. Serratus Anterior pull string; MUL, m. Lumbar Multifidus; LDO, m. Latissimus Dorsi; TRZ, m. Upper Trapezius; SESB, m. Serratus Anterior stabilizes the bow; DEP, m. Posterior Deltoid.

Table 43 described the cross-correlation (signal correlated with another signal) and coefficient of determination (coactivation index) between motor muscles. Forearm muscles obtained inverse relationship between them. m. Flexor Digitorum Superficialis presented that there was strong correlation with m. Triceps Brachii, m. Pectoralis Major Clavicular Head and m. Posterior Deltoid, but m. Flexor Digitorum Superficialis presented that there was not strong correlation with m. Extensor Digitorum and m. Biceps Brachii Long Head. m. Extensor Digitorum presented that there was strong correlation with m. Biceps Brachii Long Head, but m. Extensor Digitorum presented that there was not strong correlation with m. Triceps Brachii, m. Pectoralis Major Clavicular Head and m. Posterior Deltoid. m. Biceps Brachii Long Head presented that there was strong correlation with m. Flexor Digitorum Superficialis, m. Triceps Brachii, m. Pectoralis Major Clavicular Head and m. Posterior Deltoid. m. Triceps Brachii presented that there was strong correlation with m. Flexor Digitorum Superficialis, m. Biceps

Brachii Long Head, m. Pectoralis Major Clavicular Head and m. Posterior Deltoid. m. Pectoralis Major Clavicular Head presented that there was strong correlation with m. Flexor Digitorum Superficialis, m. Biceps Brachii Long Head, m. Triceps Brachii and m. Posterior Deltoid. M. Posterior Deltoid presented that there was strong correlation with m. Flexor Digitorum Superficialis, m. Biceps Brachii Long Head, m. Triceps Brachii and m. Pectoralis Major Clavicular Head.

Table 43 showed the cross-correlation (signal correlated with another signal) and coefficient of determination (coactivation index) between postural muscles. M. Rectus Abdominis presented that there was strong correlation with m. Lumbar Multifidus, m. Latissimus Dorsi and m. Upper Trapezius, but m. Rectus Abdominis presented that there was not strong correlation with m. Serratus Anterior pull string and m. Serratus Anterior stabilizes the bow. m. Serratus Anterior pull string presented that there was strong correlation with m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius and m. Serratus Anterior stabilizes the bow, but m. Serratus Anterior pull string presented that there was not strong correlation with m. Rectus Abdominis. M. Lumbar Multifidus presented that there was strong correlation with all postural muscles (m. Rectus Abdominis, m. Serratus Anterior stabilizes the bow, m. Latissimus Dorsi, m. Upper Trapezius and m. Serratus Anterior stabilizes the bow). M. Latissimus Dorsi presented that there was strong correlation with all postural muscles (m. Rectus Abdominis, m. Serratus Anterior pull string, m. Lumbar Multifidus, m. Upper Trapezius and m. Serratus Anterior stabilizes the bow). M. Upper Trapezius Dorsi presented that there was strong correlation with all postural muscles (m. Rectus Abdominis, m. Serratus Anterior stabilizes the bow, Lumbar Multifidus, m. Latissimus Dorsi and m. Serratus Anterior stabilizes the bow). M. Serratus Anterior stabilizes the bow presented that there was strong correlation with m. Serratus Anterior pull string, m. Lumbar Multifidus and m. Upper Trapezius, but m. Serratus Anterior stabilizes the bow presented that there was not strong correlation with m. Rectus Abdominis Anterior and m. Latissimus Dorsi.

Table 43 reported the cross-correlation (signal correlated with another signal) and coefficient of determination (coactivation index) between postural and motor muscles. M. Flexor Digitorum Superficialis presented that there was strong correlation with m. Rectus Abdominis Anterior, m. Latissimus Dorsi and m. Upper Trapezius, but m. Flexor Digitorum Superficialis presented that there was not strong correlation with m. Serratus Anterior pull string, m. Lumbar

Multifidus and m. Serratus Anterior stabilizes the bow. M. Extensor Digitorum presented that there was strong correlation with m. Serratus Anterior pull string, but m. Extensor Digitorum presented that there was not strong correlation with m. Rectus Abdominis Anterior, m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius and m. Serratus Anterior stabilizes the bow. M. Triceps Brachii, m. Pectoralis Major Clavicular Head and m. Posterior Deltoid presented that there was strong correlation with all postural muscles (m. Rectus Abdominis Anterior, m. Serratus Anterior pull string, m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius and m. Serratus Anterior stabilizes the bow). M. Biceps Brachii Long Head presented that there was strong correlation with m. Serratus Anterior pull string, m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius and m. Serratus Anterior stabilizes the bow, but m. Biceps Brachii Long Head presented that there was not strong correlation with m. Rectus Abdominis Anterior.

4.1 Muscle electrical activity in APA

APA affected 11 muscles similarly in comparison by phases. Anticipatory activity in m. Flexor Digitorum Superficialis, m. Extensor Digitorum, m. Biceps Brachii Long Head, m. Triceps Brachii, m. Pectoralis Major Clavicular Head, m. Rectus Abdominis Anterior, m. Serratus Anterior pull string, m. Latissimus Dorsi, m. Upper Trapezius, m. Serratus Anterior stabilizes the bow, m. Posterior Deltoid were higher during APA1 than APA2, APA3, Pre-APA and Rest Time. M. Biceps Brachii Long Head and m. Pectoralis Major Clavicular Head were higher during APA2 than APA3, Pre-APA and Rest Time. These muscles increase its activity throughout the APA. Activity these muscles suggest increase postural demand before the release arrow. However, one muscle was unaffected in APA in the comparison by phases. Anticipatory phase has its activity unaffected after clicker fall in m. Lumbar Multifidus. This muscle sustains its activity in APA and the postural demand not change before the release arrow.

APA affected each muscle differently in comparison 12 blocks of 6-arrows. In m. Flexor Digitorum Superficialis (APA1 and APA2), m. Triceps Brachii (APA3 and Pre-APA), m. Rectus Abdominis Anterior (APA2), m. Serratus Anterior pull string (Pre-APA and Rest Time), m. Lumbar Multifidus (all APA), m. Latissimus Dorsi (APA2), m. Upper Trapezius (APA1), m. Serratus Anterior stabilizes the bow (all APA) were affected by blocks of 6-arrows in all APA.

Modulation activity these muscles change postural demand in the blocks of 6-arrows after the release arrow. However, some muscles were unaffected in the APA in the comparison 12 blocks of 6-arrows. M. Extensor Digitorum, m. Biceps Brachii, m. Pectoralis Major Clavicular Head and m. Posterior Deltoid were unaffected by blocks of 6-arrows in APA. Anticipatory activity across blocks not changes its activity and the electrical activity is sustained in the 12 blocks of 6-arrows in APA.

4.2 MUSCLE ELECTRICAL ACTIVITY IN CPA

CPA affected each muscle differently in comparison by phases. Compensatory activity in m. Extensor Digitorum, m. Biceps Brachii, m. Triceps Brachii, m. Serratus Anterior pull string and m. Upper Trapezius were higher during CPA1 than CPA2 and CPA3; m. Pectoralis Major Clavicular Head was higher during CPA1 than CPA3. These muscles decrease its activity throughout the CPA. Activity these muscles suggest that postural demand reduce after the release arrow. However, some muscles were unaffected in the CPA in the comparison by phases. Compensatory phase has its activity unaffected after clicker fall in m. Flexor Digitorum Superficialis, m. Rectus Abdominis Anterior, m. Lumbar Multifidus, m. Latissimus Dorsi, m. Serratus Anterior stabilizes the bow and m. Posterior Deltoid. These muscles sustain its activity in M phase and the postural demand not change after the release arrow.

CPA affected each muscle differently in comparison 12 blocks of 6-arrows. In m. Triceps Brachii (CPA2 and CPA3), m. Rectus Abdominis Anterior (CPA1), m. Lumbar Multifidus (all CPA) and m. Serratus Anterior stabilizes the bow (all CPA) were affected by blocks of 6-arrows in CPA. Modulation activity proposes that the postural demand change in the blocks of 6-arrows after the release arrow. However, some muscles were unaffected in the CPA in the comparison 12 blocks of 6-arrows. M. Flexor Digitorum Superficialis, m. Extensor Digitorum, m. Biceps Brachii, m. Pectoralis Major Clavicular Head, m. Serratus Anterior pull string, m. Latissimus Dorsi and m. Upper Trapezius and m. Posterior Deltoid were unaffected by blocks of 6-arrows in CPA. Modulation activity across blocks not changes its activity and the electrical activity is sustained in the 12 blocks of 6-arrows in CPA.

4.3 MUSCLE ELECTRICAL ACTIVITY IN M PHASE

M affected each muscle differently in comparison by phases. Modulation activity in m. Extensor Digitorum was higher during M1 than M3, and M2 than M3; m. Biceps Brachii Long Head was higher during M1 than M2 and M3 and m. Triceps Brachii was higher during M1 than M3 and M2 than M3. M. Extensor Digitorum, m. Biceps Brachii Long Head and m. Triceps Brachii decreases its activity along the M. Modulation activity these muscles suggest that postural demand reduce after the release arrow. However, some muscles were unaffected in M phase by comparison in phases. Modulation phase has its activity unaffected after clicker fall in m. Flexor Digitorum Superficialis, m. Pectoralis Major Clavicular Head, m. Rectus Abdominis Anterior, m. Serratus Anterior pull string, m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius, m. Serratus Anterior stabilizes the bow and m. Posterior Deltoid. These muscles sustain its activity in M phase and postural demand not change after the release arrow.

M phase affected each muscle differently in across 12 blocks of 6-arrows. In m. Biceps Brachii (M1 and M2), m. Triceps Brachii (M3), m. Lumbar Multifidus (all M), m. Latissimus Dorsi (M2 and M3) and m. Serratus Anterior stabilizes the bow (all M) were affected by blocks of 6-arrows in M. Modulation activity proposes that the postural demand changes in the blocks of 6-arrows after the release arrow. However, some muscles were unaffected in M within the 12 blocks of 6-arrows. M. Flexor Digitorum Superficialis, m. Extensor Digitorum, m. Pectoralis Major Clavicular Head, m. Rectus Abdominis Anterior, m. Serratus Anterior pull string, m. Upper Trapezius and m. Posterior Deltoid were unaffected by blocks of 6-arrows in M phase. Modulation activity across blocks not changes its activity and the muscle electrical activity is sustained in the 12 blocks of 6-arrows in M phase.

5 DISCUSSION

Based in the results, our study answered the questions of research problem: 1- what is the EMG temporal pattern of upper limb muscles of archery athletes in the task of shooting an arrow? The postural control increased the muscle activity before the clicker fall and decreases the activity after clicker fall; 2- what is the coordination of the temporal pattern of the upper limb of the set of muscles of the archery athletes on the task to shoot an arrow? The coordination of the temporal pattern of muscles of the archery athletes to shoot an arrow is based in anticipatory and compensatory phases.

The purpose of the study was analyzing electrical activity of archers in shoot an arrow. However, since its underlying H_A was confirmed, the electrical activity of the muscles analyzed in the task of shooting an arrow to the target does not have the same temporal pattern.

The first specific objective was described and analyze the temporal pattern of electromyographic activity of upper limb muscles of archery in the task of shooting an arrow, the discussion about the result is explored in this first part discuss the results of One-way ANOVA and Tukey Test between APA, CPA and M.

5.1 ANTICIPATORY POSTURAL ADJUSTMENT

M. Flexor Digitorum Superficialis and m. Extensor Digitorum were more active in APA1 than APA2, APA3, Pre-APA and Rest Time. M. Flexor Digitorum Superficialis and m. Extensor Digitorum increases its activity throughout the APA. Anticipatory activity enhance in m. Flexor Digitorum Superficialis suggests that the postural demand of these muscles increases with the proximity to release arrow. Forearm muscle strategy can be defined in two ways: active contraction or relaxation of m. Extensor Digitorum, this muscle considered for Nishizono et al. (1987) as key muscle in the releasing activity of the bowstring (18). Some authors obtained the same result in the analysis of the bowstring release strategy which described the muscle strategy (17,18,49). Before the shot, isometric forearm muscular activity by three-finger hooking show a delicate pull and push balance should be established on the bowstring by coordinated of forearm muscles. Metacarpophalangeal, proximal and distal interphalangeal joints are fixed at a certain position. The balance between forearm muscle demonstrates this isometric forearm muscular activity before the release arrow. Arrow release happens after clicker fall (17). Tinazci (2011) presents the idea that releasing occurs to hand muscles (11). However, our study found that the pattern of activation changed in several muscles before and after clicker as described in the paragraphs above. Other authors also verified the role of other muscles beyond the forearm and described their importance to release arrow, as well as, different functions during movement (17,18,49). This result showed that there is modulation of muscle activity before releasing the arrow due to increase of activity in m. Flexor Digitorum Superficialis and m. Extensor Digitorum.

Activation of m. Flexor Digitorum Superficialis was affected by blocks of 6-arrows in phase APA1 and APA2 and m. Extensor Digitorum was not affected by blocks of 6-arrows. Anticipatory activity of m. Flexor Digitorum Superficialis suggests that the postural demand change during blocks of 6-arrows, but anticipatory activity of m. Extensor Digitorum suggests that the postural demand not change during blocks of 6-arrows. Muscle activity of m. Extensor Digitorum suggests that the postural demand is sustained during blocks of 6-arrows in APA, but muscle activity of m. Flexor Digitorum Superficialis suggests that the postural demand is varied during blocks of 6-arrows in APA. On the one hand, studies of muscle activity in forearm movement analyze coordination and different types of release strategies (7,17,49). On the other hand, Ganter et al., (2010) describe that taking the large number of shots undertaken in one competition into account, the shooting movement of the archer is required to be highly reproducible (16). Results clarified that the change modulation between blocks of 6-arrows in muscle activity of m. Flexor Digitorum Superficialis affected earlier releasing the arrow. But m. Extensor Digitorum maintains the same demand of muscle activity between blocks of 6-arrows before the release arrow.

Anticipatory activity in m. Biceps Brachii was higher during APA1 than APA2, APA3, Pre-APA and Rest Time; and APA2 than APA1, APA3, Pre-APA and Rest Time. M. Triceps Brachii was higher during APA1 than APA2, APA3, Pre-APA and Rest Time. M. Biceps Brachii and m. Triceps Brachii increases its activity throughout the APA. Anticipatory activity increases in m. Biceps Brachii and m. Triceps Brachii suggests that the postural demand of these muscles increase with the proximity to release arrow. For Soylu, Ertan and Korkusuz, (2006) the pulling the bowstring by drawing the arm includes the elbow flexed by concentric contraction of m. Biceps Brachii and m. Brachialis (7). Suwarganda et al. (2012) report that muscle activity levels of m. Triceps Brachii determined score for the archer with lower arrow speed while variation in muscle activity ascertained score for the archers with higher speed. However, the varied muscle activity influencing score and speed of individual manner (6). This result showed that there is modulation of increase muscle activity before the release arrow to m. Biceps Brachii and m. Triceps Brachii.

M. Biceps Brachii was not affected by blocks of 6-arrows in APA and m. Triceps Brachii was affected by blocks of 6-arrows in phase APA3 and Pre-APA. Anticipatory activity of m. Biceps Brachii suggests that the postural demand not change during blocks of 6-arrows, but anticipatory activity of m. Triceps Brachii suggests that the postural demand change during blocks of 6-arrows. Muscle activity of m. Biceps Brachii suggests that the postural demand is sustained during blocks of 6-arrows in APA, but muscle activity of m. Triceps Brachii suggests that the postural demand is varied during blocks of 6-arrows in APA. Cram, Kasman and Holtz (1998) describe that the action of m. Biceps Brachii is the flexion of the forearm, supination and flexion of the shoulder (95). In addition, Kapandji (2000) explained that m. Biceps Brachii is the main flexor of the elbow, and its secondary action is supination (106). M. Biceps Brachii is important to indicate ability according to Clarys et al. (1990), the ability is possible by constancy of neuromuscular control, primarily, m. Trapezius in the beginning of the draw movement, m. Biceps Brachii during the aiming phase and m. Extensor Digitorum during the release phase (28). Furthermore, at full draw the muscular activity of m. Biceps Brachii is important to reduce the humeral tremor (23,51). This result demonstrated that archer holds the elbow flexion before the arrow by means of m. Biceps Brachii. According to Jarmey (2008), m. Triceps Brachii stabilizes the shoulder joint and assists in the throw movement (107). This result showed that archer changes his demand for stabilization of the shoulder during blocks. Results clarified that the change modulation across blocks of 6-arrows in muscle activity of m. Triceps Brachii affected earlier releasing the arrow. But m. Biceps Brachii maintains the same demand across blocks of 6-arrows before release arrow.

M. Pectoralis Major Clavicular Head was higher during APA1 than APA2, APA3, Pre-APA and Rest Time; and APA2 than APA1, APA3, Pre-APA and Rest Time. M. Pectoralis Major Clavicular Head increase activity throughout the APA. Anticipatory activity increases in m. Pectoralis Major Clavicular Head suggests that the postural demand increases with the proximity to release arrow. Ahmad et al. (2014) proposed that during archery shooting, the upper limb muscles are more active due to need to pull and hold the bow until the arrow is released. This movement demands extremely vigorous muscle and more strength to pull and hold the bow in the forearm muscles and involved m. Pectoralis Major (24). This result showed that there is modulation of muscle activity before the release arrow increase of activity in m. Pectoralis Major Clavicular Head before clicker fall.

Before clicker fall, m. Pectoralis Major Clavicular Head was not affected by blocks of 6-arrows in APA. Anticipatory activity during the blocks m. Pectoralis Major Clavicular Head not changes its activity throughout in blocks of 6-arrows in APA. Muscle activity of m. Pectoralis Major Clavicular Head suggests that the postural demand is sustained during blocks of 6-arrows in APA. Pulling the bowstring by drawing the arm requires a flexion of the elbow. Overall movement of release, the bow arm is responsible for pushing the bow and adjusting the placement of sight on the target by resisting the force from the drawing arm. The pectoral girdle is protected by concentric shortening of m. Trapezius, m. Rhomboid Major and m. Rhomboid Minor. In pushing (movement of the bow) occurs abduction and flexion of the shoulder, one of the muscles that rapidly flexed the shoulder is m. Pectoral Major concentrically (7). This outcome indicates the temporal pattern across blocks of m. Pectoralis Major Clavicular Head before clicker fall.

M. Rectus Abdominis Anterior was higher during APA1 than APA2, APA3, Pre-APA and Rest Time. M. Rectus Abdominis Anterior increases its activity throughout the APA. Anticipatory activity increases in m. Rectus Abdominis Anterior suggests that the postural demand increases with the proximity to release arrow. According to Drake, Vogl and Mitchell (2012), m. Rectus Abdominis is an important muscle for compress abdomen, flex spine, tense abdominal wall and during respiration (108). This result showed that there is modulation of muscle activity before release arrow due to increase activity in m. Rectus Abdominis Anterior.

Activation of m. Rectus Abdominis Anterior was affected by blocks of 6-arrows in phase APA2. During the blocks m. Rectus Abdominis Anterior changes its activity throughout in blocks of 6-arrows in APA. Anticipatory activity of m. Rectus Abdominis suggests that the postural demand vary during blocks of 6-arrows in APA. For Muscolino (2016), the action of m. Rectus Abdominis is isometric stabilization of the spinal joint, pelvis and rib cage (109). This result clearly that modulation change between blocks of 6-arrows, m. Rectus Abdominis Anterior was affected APA2 before clicker fall.

Anticipatory activity in m. Serratus Anterior pull string was higher during APA1 than APA2, APA3, Pre-APA and Rest Time. M. Serratus Anterior pull string increases its activity throughout the APA. Anticipatory activity increases in m. Serratus Anterior pull string suggests that the postural demand of increases with the proximity to release arrow. The isometric action of m. Serratus Anterior stabilizes the scapula and stabilizes the rib cage (109). This outcome showed the modulation of muscle activity in m. Serratus Anterior pull string is different before releasing the arrow. Likewise, m. Serratus Anterior stabilizes the bow was higher during APA1 than APA2, APA3, Pre-APA and Rest Time. M. Serratus Anterior stabilizes the bow increases its activity throughout the APA. Anticipatory activity increases in m. Serratus Anterior stabilizes the bow suggests that the postural demand of increases with the proximity to release arrow. M. Serratus Anterior is essential for maintaining a healthy posture of the scapula by stabilization of the scapula. The muscle is relevant for preventing lateral tilt (winging) and upward tilt of the scapula (109). This outcome showed the modulation of muscle activity in m. Serratus Anterior is different before the release arrow.

M. Serratus Anterior pull string was affected by blocks of 6-arrows in phase Pre-APA and Rest Time. During the blocks m. Serratus Anterior pull string changes its activity throughout in blocks of 6-arrows in APA. Anticipatory activity of m. Serratus Anterior pull string suggests that the postural demand vary during blocks of 6-arrows in APA. In addition, m. Serratus Anterior stabilizes the bow was affected by blocks of 6-arrows in all APA (APA1, APA2, APA3, Pre-APA and Rest Time). During the blocks m. Serratus Anterior stabilizes the bow changes its activity throughout in blocks of 6-arrows in APA. Anticipatory activity of m. Serratus Anterior stabilizes the bow suggests that the postural demand vary during blocks of 6-arrows in APA. One of the muscles that have been shown to be important within the shot cycle, especially at full draw is m. Serratus Anterior (23,46,51). Additionally, scapular muscle amplitude plays an important stabilizing role in reducing humerus tremor during archery performance (51). This result clearly that the change of modulation between blocks of 6-arrows in muscle activity of m. Serratus Anterior pull string affected Pre-APA and Rest Time for stabilizes the scapula and rib cage isometric function. In addition, m. Serratus Anterior change activity during blocks of 6-arrows.

M. Lumbar Multifidus does not change during APA. M. Lumbar Multifidus maintain its activity throughout the APA. Anticipatory activity in m. Lumbar Multifidus suggests that the postural demand not change with the proximity to release arrow. In the lumbar region, m.

Multifidus it is especially in the inferior intervertebral joints, where they are the main posterior stabilizers, their muscular mass present greater size (110). M. Multifidus stabilizes the spinal joints, sacroiliac joint and core stabilization in isometric contraction (109). In addition, m. Lumbar Multifidus and minimize spinal or pelvic movement (111). This result showed that there is not modulation of muscle activity before release arrow due to sustained of activity in m. Lumbar Multifidus.

Before the clicker fall, m. Lumbar Multifidus was affected by blocks of 6-arrows in all APA (APA1, APA2, APA3, Pre-APA and Rest Time). During the blocks m. Lumbar Multifidus changes its activity throughout in blocks of 6-arrows in APA. Anticipatory activity of m. Lumbar Multifidus suggests that the postural demand vary during blocks of 6-arrows in APA. M.Multifidus (described as plural) protect the vertebral joints of movements produced by more powerful superficial agonist muscles; this muscle help maintains posture and stability of the spine during movement (107). Knox et al. (2016) show the importance of postural control in lumbar, the ineffectually postural control by CNS during disturbance increases the risk of excess forces in the spine, contributing to the low back pain. In addition, m. Multifidus are considered the main responsible for intervertebral movements (112). Results clarified that the change modulation between blocks of 6-arrows in muscle activity of m. Lumbar Multifidus affected earlier to release arrow.

M. Latissimus Dorsi was higher during APA1 than APA2, APA3, Pre-APA and Rest Time. The Latissimus Dorsi increases its activity throughout the APA. Anticipatory activity increases in m. Latissimus Dorsi suggests that the postural demand increases with the proximity to release arrow. As reported by Muscolino (2016), m. Latissimus Dorsi stabilizes the glenohumeral joint, spinal joint and scapula in isometric contraction (109). In archery, the action pulling the bowstring by drawing the arm m. Latissimus Dorsi extended shoulder by the concentric action in the movement (7). This outcome indicates temporal pattern of m. Latissimus Dorsi before clicker fall.

Activation of m. Latissimus Dorsi was affected by blocks of 6-arrows in phase APA2. During the blocks m. Latissimus Dorsi changes its activity throughout in blocks of 6-arrows in APA. Anticipatory activity of m. Latissimus Dorsi suggests that the postural demand vary during blocks of 6-arrows in APA. Lin et al. (2010) (51) and Spratford, Campbell (2017) observed that the fluctuations during shot provided principally from the humerus (the least amount in the scapula) and the related factors in these fluctuations may influence shot (23). M. Latissimus Dorsi stabilize and reducing humerus tremor during archery performance. This result showed that there is modulation of muscle activity before the release arrow due to increase activity in m. Latissimus Dorsi.

Anticipatory activity m. Upper Trapezius was higher during APA1 than APA2, APA3, Pre-APA and Rest Time. M. Upper Trapezius increases its activity throughout the APA. Anticipatory activity increases in m. Upper Trapezius suggests that the postural demand increases with the proximity to release arrow. In more detail Kolayiş and Ertan (2016) explain that m. Trapezius Middle is responsible from adduction of scapula and this muscle contracts symmetrically in drawing arm and in bow arm to share the weight of the drawing bow before the shot (21). In addition, Soylu, Ertan and Korkusuz (2006) described that the pectoral girdle is protected by concentric shortening of m. Trapezius, m. Rhomboid Major and m. Rhomboid Minor (7). This result showed that there is not modulation of muscle activity before the release arrow due to sustained of activity in m. Upper Trapezius.

M. Upper Trapezius was affected by blocks of 6-arrows in phase APA1. During the blocks, m. Upper Trapezius changes its activity throughout in blocks of 6-arrows in APA. Anticipatory activity of m. Upper Trapezius suggests that the postural demand vary during blocks of 6-arrows in APA. Clarys et al. (1990) emphasize that m. Trapezius demonstrated the earliest contraction both in the bow and draw-arm, confirming that the shoulder muscles are the initiators of the draw movement (elevation of arm and scapula; pulling the scapula upwards and medially) (28). Any authors reveal that m. Trapezius reduce tremor of the scapular (23,43,51). Results clarified that the change modulation between blocks of 6-arrows in muscle activity of m. Upper Trapezius affected earlier releasing the arrow.

M. Posterior Deltoid was higher during APA1 than APA2, APA3, Pre-APA and Rest Time. M. Posterior Deltoid increases its activity throughout the APA. Anticipatory activity increases in m. Posterior Deltoid suggests that the postural demand increases with the proximity to release arrow. In the shoulder joint, m. Deltoid is important for drawing arm force depends on the strength of that muscle (24). M. Deltoid can be considered an important muscle in the pull arm's movement (43) and provides shoulder joint stability at release (43,113). Pulling the bowstring by drawing the arm includes the elbow flexed while the shoulder is extended by the strong concentric action of m. Posterior Deltoid. During the pushing movement of the bow by abduction and flexion of the shoulder, the shoulder is maintained in abduction by isometric contraction of m. Middle Deltoid, and is then rapidly flexed by m. Anterior Deltoid and m. Pectoralis Major (7). This outcome indicates the temporal pattern of m. Posterior Deltoid before clicker fall.

Activation of m. Posterior Deltoid was not affected by blocks of 6-arrows in phase APA1, APA2, APA3, Pre-APA and Rest Time. During the blocks m. Posterior Deltoid not changes its activity throughout in blocks of 6-arrows in APA. Anticipatory activity of m. Posterior Deltoid that the postural demand is sustained during blocks of 6-arrows in APA. M. Deltoid reduce the tremor humeral (23,51) because minimize fluctuations in high strength muscle performance with 90º of elevation in the full drawing position may be a suitable position for demands in archery. In the same way, it can be considered that the isometric functions of m. Deltoid is stabilizes glenohumeral joint and stabilizes scapula and clavicle (109). M. Middle Deltoid can be said that is the main carrier of the bow weight on bow arm because in drawing arm muscles, iEMG% is higher in m. Middle Deltoid side bow arm muscles and it follows with m. Posterior Deltoid. Bow arm stabilizes the bow and weight bow, approximately 10 kg (21). his result showed that m. Posterior Deltoid increases activity before the release arrow.

5.2 Compensatory Postural Adjustment

M. Flexor Digitorum Superficialis showed no difference in muscle activity in CPA. M. Flexor Digitorum Superficialis sustains its activity throughout the CPA. Compensatory activity in m. Flexor Digitorum Superficialis suggests that the postural demand not change after the release arrow. But, m. Extensor Digitorum was higher during CPA1 than CPA2 and CPA3. M. Extensor Digitorum decreases its activity throughout the CPA. Anticipatory activity lower in m. Extensor Digitorum suggests that the postural demand reduce after the release arrow. According to the level of archers, Ertan at al. (2003) all archers progressively relaxed of m. Flexor Digitorum Superficialis after clicker fall and relaxation was more rapid in elite archers than in beginners and non-archer (17). One female elite archer showed a significant decrease activity m. Extensor Digitorum at 100ms after clicker fall when compared with other elite archers. This study was consistent with Martin, Siler, Hoffman (1990) who found two distinct contraction groups. The first strategy is relaxation of the flexor muscle and second stratey is relaxation of the flexors and contraction of the extensors (49). The second group is the same strategy to release the bowstring as Nishozono et al. (1987) (18). This result showed that there is modulation of muscle activity after releasing the arrow due to sustain activity in m. Flexor Digitorum Superficialis and decreases activity in m. Extensor Digitorum.

Activation of m. Flexor Digitorum Superficialis and m. Extensor Digitorum were not affected by blocks of 6-arrows in CPA. Compensatory activity of m. Flexor Digitorum Superficialis and m. Extensor Digitorum suggests that the postural demand not change during blocks of 6-arrows. Muscle activity of m. Flexor Digitorum Superficialis and m. Extensor Digitorum suggests that the postural demand is sustained during blocks of 6-arrows in CPA after release arrow. Martin, Siler, Hoffman (1990) reported that coaches recommend that archers which release the bowstring by relaxation of the muscles that flexed fingers around the string (49). Because the force string on the fingers is sufficient to produce their extension and consequently the smoother release arrow. At that time, the hypothesis was that an active extension of the fingers produces lateral deflections of the bowstring and less consistent shot-to-shot performance. The small intra-individual variations in the activation patterns of the forearm muscle suggest that it may not be the mechanism that distinguishes archers of different skill level, but rather their ability to reproduce a particular mechanism consistently from shot-to-shot. In the intention to avert gripping the bow-handle the forearm flexor and extensor muscles relax or not activate. Flexor muscles could grip the bow and disturb the shot, in addition, decrease the score on target. Other point of the authors was the fact elite archers had a greater activation of m. Extensor Digitorum, the found indicates that they prevent gripping the bow-handle not only relaxing the flexor muscles, but also contracting the extensor muscle groups. This strategy ensures the forward movement of the bow without disturbance to release caused when pushing of the bowstring (10). Research that focus on the finger motion in three-dimensional way. Authors were inspired in Cerveri et al. (2007) due to motion analyses of finger and hand motion (114). Motor program of arrow release in the manner of an open-loop movement is already initiated before clicker fall (50). Results clarified that m. Flexor Digitorum Superficialis and m. Extensor Digitorum maintains the same demand across blocks of 6-arrows after the release arrow.

Compensatory activity in m. Biceps Brachii Long Head, m. Triceps Brachii, m. Serratus Anterior pull string and m. Upper Trapezius were higher during CPA1 than CPA2 and CPA3. For m. Pectoralis Major Clavicular Head was higher during CPA1 than CPA3. M. Biceps Brachii

Long Head, m. Triceps Brachii, m. Pectoral Major, m. Serratus Anterior pull string and m. Upper Trapezius decreases its activity throughout the CPA. Compensatory activity in m. Biceps Brachii Long Head, m. Triceps Brachii, m. Pectoral Major, m. Serratus Anterior pull string and m. Upper Trapezius suggests the reduction of postural demand after release arrow. Reduction of muscle activity after clicker fall is found in m. Extensor Digitorum, m. Flexor Digitorum Superficialis (9), m. Trapezius Middle and m. Trapezius Lower (21). Ertan et al. (2011) showed the relaxation of m. Flexor Digitorum Superficialis approximately 100ms after clicker fall and gradual relaxation of m. Extensor Digitorum after clicker fall (9). This result showed that there is modulation of muscle activity after releasing the arrow due to decrease activity in m. Biceps Brachii, m. Triceps Brachii, m. Pectoral Major, m. Serratus Anterior pull string and m. Upper Trapezius.

M. Triceps Brachii, m. Rectus Abdominis Anterior (CPA1), m. Lumbar Multifidus (all CPA) and m. Latissimus Dorsi (CPA1) were affected by blocks of 6-arrows in phase CPA. Compensatory activity of m. Triceps Brachii, m. Rectus Abdominis Anterior, m. Lumbar Multifidus and m. Latissimus Dorsi suggests that the postural demand changes its activity throughout in blocks of 6-arrows in CPA. Muscle activity of m. Triceps Brachii, m. Rectus Abdominis Anterior, m. Lumbar Multifidus and m. Latissimus Dorsi suggests that the postural demand is varied during blocks of 6-arrows in CPA after the release arrow. It is known that there is a reduction in muscle demand after clicker fall (9,17,21). Results clarified that the change modulation between blocks of 6-arrows in muscle activity of m. Triceps Brachii, m. Rectus Abdominis Anterior, m. Lumbar Multifidus and m. Latissimus Dorsi were affected after releasing the arrow.

M. Rectus Abdominis Anterior, m. Lumbar Multifidus, m. Serratus Anterior stabilizes the bow and m. Posterior Deltoid were unaffected by CPA after clicker fall. M. Rectus Abdominis Anterior, m. Lumbar Multifidus, m. Serratus Anterior stabilizes the bow and m. Posterior Deltoid sustains its activity in CPA. Compensatory activity in m. Rectus Abdominis Anterior, m. Lumbar Multifidus, m. Serratus Anterior stabilizes the bow and m. Posterior Deltoid suggests that the postural demand not change with the proximity to release arrow. M. Middle Deltoid that sustains its muscular activity without variation due to function muscle, this muscle is the main carrier of the bow weight in the bow arm (21). This outcome showed that modulation not change after releasing the arrow due to maintenance of muscle activity in m. Rectus Abdominis Anterior, m.

Lumbar Multifidus, m. Serratus Anterior stabilizes the bow and m. Posterior Deltoid after clicker fall.

After clicker fall, m. Biceps Brachii, m. Pectoralis Major Clavicular Head, m. Serratus Anterior pull string, m. Serratus Anterior stabilizes the bow, m. Latissimus Dorsi, m. Upper Trapezius and m. Posterior Deltoid were not affected by blocks of 6-arrows in phase CPA. Compensatory activity during the blocks m. Biceps Brachii, m. Pectoralis Major Clavicular Head, m. Serratus Anterior pull string, m. Serratus Anterior stabilizes the bow, m. Latissimus Dorsi, m. Upper Trapezius and m. Posterior Deltoid not vary its activity throughout in blocks of 6-arrows in CPA. Muscle activity of m. Biceps Brachii, m. Pectoralis Major Clavicular Head, m. Serratus Anterior pull string, m. Serratus Anterior stabilizes the bow, m. Latissimus Dorsi, m. Upper Trapezius and m. Posterior Deltoid suggests that the postural demand is maintained during blocks of 6-arrows in CPA after the release arrow. Likewise, this result showed that the modulation not change between blocks of 6-arrows in muscle activity of m. Biceps Brachii, m. Pectoralis Major Clavicular Head, m. Serratus Anterior pull string, m. Serratus Anterior stabilizes the bow, m. Latissimus Dorsi, m. Upper Trapezius and m. Posterior Deltoid after releasing the arrow.

5.3 Modulation

M. Flexor Digitorum Superficialis showed no difference in muscle activity in M phase. M. Flexor Digitorum Superficialis sustains its activity throughout the M phase. Modulation activity in m. Flexor Digitorum Superficialis suggests that the postural demand not change after the release arrow. But, m. Extensor Digitorum was higher during M1 than M3 and M2 than M3. M. Extensor Digitorum decreases its activity throughout the M phase. Modulation activity lower in m. Extensor Digitorum suggests that the postural demand reduce after the release arrow. For Martin, Siler, Hoffman (1990) all archers present similar activation pattern for m. Flexor Digitorum Superficialis because after a constant phase of muscle activity for the first 900ms of the analysis period, the archers displayed a notable decrease in iEMG for the 100ms interval immediately preceding release. Muscle activity then continued to decline for the remainder of the analysis period. The justification for the difference found by our study can be explained by the justification that the authors insert in the paper. Flexor decline activity after clicker fall to contribute to a reduction in the flexor moments acting about the joints of the fingers, facilitating extension of the fingers. Still, the authors reported that the closure of the clicker on the bow, which occurred on average 185ms prior to release (49). According to our results, some muscles decrease activation before the arrow is released. This result showed that there is modulation of muscle activity after releasing the arrow due to activity in m. Flexor Digitorum Superficialis and m. Extensor Digitorum.

Activation of m. Flexor Digitorum Superficialis and m. Extensor Digitorum were not affected by blocks of 6-arrows in M phase. Modulation activity of m. Flexor Digitorum Superficialis and m. Extensor Digitorum suggests that the postural demand not change during blocks of 6-arrows in M phase. Muscle activity of m. Flexor Digitorum Superficialis and m. Extensor Digitorum suggests that the postural demand is sustained during blocks of 6-arrows in M phase after the release arrow. This result is supported for Ertan (2009), m. Flexor Digitorum Superficialis and m. Extensor Digitorum returned to their baseline values at about 300ms. These muscles reached their peak amplitude at 200ms and directly begin relaxation after the peak amplitude. During the shot, elite archers relax their finger flexors for not to grip the bow-handle and contract extensors to avoid holding/gripping the handle during the whole shot. But, the authors explain that the strategy by elite archers alters at about 200ms after clicker fall by active contraction of forearm muscles. The archers equalize the values of both muscle groups and reach equilibrium and return to the pre-clicker values. Therefore, the equalize contraction levels of muscles to not to change the range of motions in metacarpophalangeal, proximal and distal interphalangeal joints. This strategy just after clicker fall can be considered an action to avoid the gripping of the bow-handle (10). However, muscle activity values were not significantly different the CPA and M after clicker fall across 12 blocks of 6-arrows for m. Flexor Digitorum Superficialis and m. Extensor Digitorum in our study. Results clarified that m. Flexor Digitorum Superficialis and m. Extensor Digitorum maintains the same demand across blocks of 6-arrows after the release arrow.

Modulation activity in m. Biceps Brachii Long Head was higher during M1 than M2 and M3 and m. Triceps Brachii was higher during M1 than M3 and M2 than M3. M. Biceps Brachii Long Head and m. Triceps Brachii decreases its activity throughout the M phase. Modulation activity lower in m. Biceps Brachii Long Head and m. Triceps Brachii suggests that the postural demand reduce after the release arrow. Some authors describe the reduction of muscle activity after clicker fall in the forearm muscles (9) and m. Trapezius Middle and m. Trapezius Lower

(21). his result showed that there is modulation of muscle activity after releasing the arrow due to decrease activity in m. Biceps Brachii and m. Triceps Brachii during M phase.

M. Biceps Brachii (M1 and M2), m. Triceps Brachii (M3), and m. Serratus Anterior stabilizes the bow, m. Lumbar Multifidus (all M phase) and m. Latissimus Dorsi (M2 and M3) were affected by blocks of 6-arrows in M phase. Modulation activity of m. Biceps Brachii, m. Triceps Brachii, m. Serratus Anterior stabilizes the bow, m. Lumbar Multifidus and m. Latissimus Dorsi proposes that the postural demand change in the blocks of 6-arrows. Muscle activity of m. Biceps Brachii, m. Triceps Brachii, m. Serratus Anterior stabilizes the bow, m. Lumbar Multifidus and m. Latissimus Dorsi suggests that the postural demand is varied across blocks of 6-arrows in M phase after the release arrow. Each muscle showed different variation in M phase. Results clarified that the change modulation across blocks of 6-arrows in m. Biceps Brachii, m. Triceps Brachii, m. Serratus Anterior stabilizes the bow, m. Lumbar Multifidus and m. Latissimus Dorsi after the release arrow.

Modulation activity in m. Pectoralis Major Clavicular Head, m. Rectus Abdominis Anterior, m. Serratus Anterior pull string, m. Serratus Anterior stabilizes the bow, m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius and m. Posterior Deltoid were unaffected by M phase after clicker fall. M. Pectoralis Major Clavicular Head, m. Rectus Abdominis Anterior, m. Serratus Anterior pull string, m. Serratus Anterior stabilizes the bow, m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius and m. Posterior Deltoid sustains activity in M phase. Modulation activity in m. Pectoralis Major Clavicular Head, m. Rectus Abdominis Anterior, m. Serratus Anterior pull string, m. Serratus Anterior stabilizes the bow, m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius and m. Posterior Deltoid not change postural demand after the release arrow. Kolayiş and Ertan (2016) described that m. Middle Deltoid and m. Posterior Deltoid are not just due to control of weight of the bow and imbalance of the string at releasing phase and this function continues after clicker fall (21). This outcome showed that modulation does not change the muscle activity after releasing the arrow due to sustained activity in m. Pectoralis Major Clavicular Head, m. Rectus Abdominis Anterior, m. Serratus Anterior pull string, m. Serratus Anterior stabilizes the bow, m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius and m. Posterior Deltoid after clicker fall. M. Lumbar Multifidus maintains activity during task, but this activity is modulated in each block.

After clicker fall, m. Pectoralis Major Clavicular Head, m. Upper Trapezius, m. Serratus Anterior pull string and m. Posterior Deltoid were unaffected by blocks of 6-arrows in M phase. Modulation activity during the blocks m. Pectoralis Major Clavicular Head, m. Upper Trapezius, m. Serratus Anterior pull string and m. Posterior Deltoid not changes its activity in blocks of 6-arrows in M phase. Muscle activity of m. Pectoralis Major Clavicular Head, m. Upper Trapezius, m. Serratus Anterior pull string and m. Posterior Deltoid suggests that the postural demand is sustained during blocks of 6-arrows in M phase after the release arrow. This result showed that the modulation not change in m. Pectoralis Major Clavicular Head, m. Upper Trapezius, m. Serratus Anterior pull string and m. Posterior Deltoid by blocks of 6-arrows in M phase after clicker fall.

5.4 Cross-correlation

Cross-Correlations analyses evaluate how well a given signal is correlated with another signal by means of correlation coefficient (93). M. Flexor Digitorum presented that there was strong correlation with m. Triceps Brachii, m. Pectoralis Major Clavicular Head. M. Extensor Digitorum presented that there was strong correlation with m. Biceps Brachii Long Head. Cross-relation between motor muscles showed that forearm muscles obtained inverse relationship between correlation coefficient them. According to Clarys et al. (1990) (28), Hennessy and Parker (1990) (113) and Nishizono et al. (1987) (18), muscular coordination between the agonist and the antagonist muscles of the forearm is essential in this strategy and requires a relatively long training period. This result showed that the EMG signal is correlated in forearm muscles and motor muscles had inverse relation between patterns of similarity level by phase.

M. Biceps Brachii Long Head presented that there was strong correlation with m. Extensor Digitorum, m. Triceps Brachii, m. Pectoralis Major Clavicular Head and m. Posterior Deltoid. M. Triceps Brachii presented that there was strong correlation with m. Flexor Digitorum Superficialis, m. Biceps Brachii, m. Pectoralis Major Clavicular Head and m. Posterior Deltoid. Arm muscles had a correlation in the muscles between them and in m. Pectoralis Major Clavicular Head and m. Posterior Deltoid. Correlation between arm and forearm muscles is inversely. Similarity of arm muscles may be to release movement along the blocks. For hold longer sustain in the shooting m. Trapezius and m. Deltoids are used to pull the string instead of

m. Biceps and m. Triceps and the forearms muscles (8–10,17,55). This finding shows similar modulation of muscle activity between arm muscles than other motor muscles.

Cross-correlation in m. Pectoralis Major Clavicular Head and m. Posterior Deltoid presented that there was strong correlation between them, m. Flexor Digitorum Superficialis, m. Biceps Brachii and m. Triceps Brachii. M. Pectoralis Major Clavicular Head and m. Posterior Deltoid showed the same correlation among motor muscles. Soylu, Ertan and Korkusuz (2006) described that during the pushing of the bow with abduction and flexion of the shoulder, the shoulder is maintained in abduction by isometric contraction of m. Middle Deltoid, and is then rapidly flexed by m. Anterior Deltoid and m. Pectoralis Major, assisted by m. Coracobrachialis and m. Biceps Brachii Long Head, all of which work concentrically (7). These results described that muscles have the same function during movement and therefore have similarities in their signals.

M. Lumbar Multifidus and m. Upper Trapezius presented that there was strong correlation between them and all postural muscles (m. Rectus Abdominis, m. Serratus Anterior pull string, m. Lumbar Multifidus, m. Latissimus Dorsi and m. Serratus Anterior stabilizes the bow). M. Lumbar Multifidus and m. Upper Trapezius showed the similar correlation between postural muscles. Soylu, Ertan and Korkusuz (2006) describe that the pulling the bowstring by drawing the arm includes the elbow flexed by concentric contraction of m. Biceps Brachii and m. Brachialis, while the shoulder is extended by concentric action of m. Teres Major, m. Latissimus Dorsi and m. Posterior Deltoid. Pectoral girdle is protected by concentric shortening of m. Trapezius, m. Rhomboid Major and m. Rhomboid Minor. But, during pushing movement of the bow by abduction and flexion of the shoulder, the shoulder is sustained in abduction due to isometric contraction of m. Middle Deltoid and is then rapidly flexed by m. Anterior Deltoid and m. Pectoralis Major, assisted by m. Coracobrachialis and m. Biceps Brachii long head, all muscles work concentrically (7). These results showed coherence between signals of m. Lumbar Multifidus and m. Upper Trapezius and all postural muscles.

Cross-correlation in m. Rectus Abdominis presented that there was strong correlation between m. Lumbar Multifidus, m. Latissimus Dorsi and m. Upper Trapezius. M. Rectus Abdominis was not presents strong correlation with m. Serratus Anterior (m. Serratus Anterior pull string and m. Serratus Anterior stabilizes the bow). Muscolino (2016) describe that m. Latissimus Dorsi stabilizes the glenohumeral joint, spinal joint and scapula during isometric contraction (109). The action of m. Rectus Abdominis is isometric stabilization of the spinal joint, pelvis and rib cage. During full draw m. Trapezius (24,28,51) and m. Latissimus Dorsi (46,51) perform full draw. These outcomes showed similar modulation for releasing the arrow between m. Rectus Abdominis, m. Lumbar Multifidus, m. Latissimus Dorsi and m. Upper Trapezius.

M. Latissimus Dorsi presented strong correlation between m. Rectus Abdominis, m. Serratus Anterior pull string, m. Lumbar Multifidus and m. Upper Trapezius. M. Latissimus Dorsi was not presents strong correlation among m. Serratus Anterior stabilizes the bow (pull the bowstring). Muscolino (2016) describe that m. Latissimus Dorsi stabilizes the glenohumeral joint, spinal joint and scapula during isometric contraction (109). The action of m. Rectus Abdominis is isometric stabilization of the spinal joint, pelvis and rib cage. Any authors describe that m. Trapezius (24,28,51) m. Latissimus Dorsi and m. Serratus Anterior (46,51) perform full draw. Results showed coherence among signals of muscles to release arrow.

Cross-correlation in m. Flexor Digitorum Superficialis presented that there was strong correlation with m. Rectus Abdominis Anterior, m. Latissimus Dorsi and m. Upper Trapezius. Any authors describe these muscles important for full draw, for example the m. Trapezius (24,28,51) and m. Latissimus Dorsi (46,51). For Soylu, Ertan and Korkusuz (2006), the shoulder is extended by concentric action of m. Teres Major, m. Latissimus Dorsi and m. Posterior Deltoid. One of the muscles that protect the Pectoral girdle is m. Trapezius (7). M. Rectus Abdominis has not been written yet. Muscolino (2016) described that the action of m. Rectus Abdominis is isometric stabilization of the spinal joint, pelvis and rib cage (109). This outcome showed m. Flexor Digitorum Superficialis, m. Rectus Abdominis Anterior, m. Latissimus Dorsi and m. Upper Trapezius is associated with release arrow in different actions. M. Flexor Digitorum Superficialis act distally action, while m. Rectus Abdominis Anterior, m. Latissimus Dorsi and m. Upper Trapezius are important for full draw.

M. Extensor Digitorum presented that there was strong correlation with m. Serratus Anterior pull string. M. Extensor Digitorum showed correlation with m. Serratus Anterior pull string, m. Serratus Anterior stabilizes the bow. As reported by Muscolino (2016), the isometric action of m. Serratus Anterior is stabilizes the scapula and stabilizes the rib (109). Whereas Nishizono et al. (1987) consider that m. Extensor Digitorum releasing bowstring (18). Active contraction of m. Extensor Digitorum was associated with a change from flexion to extension to release arrow (113). This result showed the association to release arrow in different actions.

Cross-correlation in m. Triceps Brachii, m. Pectoralis Major Clavicular Head and m. Posterior Deltoid presented that there was strong correlation with all postural muscles (m. Rectus Abdominis Anterior, m. Serratus Anterior pull string, m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius and m. Serratus Anterior stabilizes the bow). M. Triceps Brachii, m. Pectoralis Major Clavicular Head and m. Posterior Deltoid showed the same correlation among postural muscles. M. Biceps Brachii Long Head presented that there was strong correlation with m. Serratus Anterior pull string, m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius and m. Serratus Anterior stabilizes the bow. M. Biceps Brachii Long Head was not showed similarity with m. Rectus Abdominis Anterior. Spratford and Campbell (2017) (23) related the muscles important to perform full draw, for example the m. Trapezius (24,28,51), m. Biceps Brachii (28,51), m. Deltoid (11,24,43,51), m. Serratus Anterior, m. Rhomboid, m. Latissimus Dorsi, m. Infraspinatus, m. Teres Minor and m. Pectoralis Major (24). Pectoral girdle is protected by concentric shortening of m. Trapezius, m. Rhomboid Major and m. Rhomboid Minor. But, during pushing movement of the bow by abduction and flexion of the shoulder, the shoulder is sustained in abduction due to isometric contraction of m. Middle Deltoid and is then rapidly flexed by m. Deltoid Anterior and m. Pectoralis Major, assisted by m. Coracobrachialis and m. Biceps Brachii Long Head, all muscles work concentrically. The result showed the importance of the synergistic action of these muscles during the full draw.

5.5 Research Question 1

The first research question is: What is the temporal pattern of upper limb muscles of archery athletes in shooting an arrow? The postural control increased the muscle activity before clicker fall and decreased the activity after clicker fall.

Temporal pattern of upper limb muscles of archery athletes in shooting an arrow is varied. Electrical activity increases in anticipatory phase due to growth in muscle demand before the release arrow and decreases activity after clicker fall in CPA and M phase by reduction of demand after release arrow. Describe the muscle strategy, in the case of this study, temporal pattern during APA, CPA and M phase to release arrow and to understand movement over time

(17,18,49). Motor task can be accomplished in different ways with numerous combinations muscle strength generating same binary sets. Muscle activation patterns of different people that perform same task as well learned are very similar. This evidence suggests that during the control of individual muscle forces, CNS uses specific principles are the same for several people (65).

In the literature, several studies analyzed muscular activation patterns in various aspects: analysis of strategy of muscular activation pattern (7,10,28), analysis of muscle strategies by performance (8,28), muscle activity of forearm muscles (8,10,17,28), forearm muscle during bowstring release (49) and of muscle patterns (28). On the whole, archery is a static sport requiring strength and endurance of upper body, in forearm and shoulder girdle (21). Ertan et al. (2003) observed that archers showed gradual relaxation of m. Flexor Digitorum Superficialis after clicker fall and relaxation was more rapid in elite archers than beginners and in non-archers (17). Nishizono et al. (1987) consider m. Extensor Digitorum as principal muscle to release arrow (18). Active contraction of m. Extensor Digitorum was associated with change from flexion to extension to release bowstring. Highly skilled archers displayed similar patterns to release arrow (21,113).

Clarys et al. (1990) found difference between Olympic and National archers. Olympic archers showed remarkable reproducible with 92% identical patterns with small variation in stabilizing the bow (28). National archers produced 41% identical and 11% conform patterns (variation across 10 muscles principally in the draw arm - m. Extensor Digitorum and m. Flexor Digitorum Superficialis - before and during the release phase. Beginner archers produced 79% conform patterns and 21% different patterns mostly in m. Trapezius. Performance differences between ability are not reflected into equal differences of muscle patterns, muscle intensity and arrow speed because some of these variables are not discriminatory enough. The main factor of discrimination is the ability to reproduce identical muscle patterns and identical arrow speeds at the time of release. This ability is possible by constancy of neuromuscular control of m. Trapezius in beginning of the draw movement, m. Biceps Brachii in aiming phase and m. Extensor Digitorum in release phase (28). Generally, in drawing arm, shoulder girdle muscles gradually increase until clicker fall especially in the second period of aiming phase. All these muscles naturally relax rapidly after clicker fall due to releasing (21).

5.6 RESEARCH QUESTION 2

Second research question is: What is the coordination of the temporal pattern of upper limb muscles of archery athletes shooting an arrow? The coordination of the temporal pattern of muscles of the archery athletes on the task to shoot an arrow is based in temporal pattern.

First, it is feasible to define coordination. Coordination is a behavior of two or more degrees of freedom in relation to each other to produce specific activities (59) and the way that movements are controlled is flexible to accommodate the variability without prejudice to the task performance (79). CNS selects particular solutions of the options offered by the muscles, joints and limbs in problem of redundant motor control (80). Coordination in archery is important because the 1) agonist and antagonist muscles reduce external interference during shooting (8,9); 2) it stabilizes the joint forearm and 3) reduces the effect of disturbances (12). Muscular coordination between agonist and antagonist forearm muscles is essential in this strategy and requires a relatively long training period (18,28,113). The shot undisturbed makes the phase reproducible release (10).

Muscle synergy uses the inherent motor solution which selects the pattern to solve the driving task and is characterized by the sharing of compensation and error (1,66). Motor system variability became the object of study of motor tasks. Synergy of movement evaluates muscle activation patterns in motor tasks (68). Synergism has been experienced with EMG across a muscle it is also used computational analyzes to identify synergies and define the use of EMG recordings (19) by quantify how elements suffer covariation in their output and the treatment of synergy is also observed in pursuit of stable sharing between patterns of output of elements of a multi-element system (115). There are several ways to perform a motor task from muscle strength combinations in the joint (49,65,82). Set of solutions is smaller than the number of solutions that experience a process of selection and or optimization. Studies based on the description and analysis of motor synergies comes to finding solutions to define the rules that organize motor solutions to perform task. Scientific paradigm by operational definition of synergy and creation approach to identify and quantify them (82,88).

Release arrow is an example of the isometric contractions in the forearm muscles of the drawing arm. Before clicker fall, the archer is not supposed to change the range of motion of the proximal and distal inter-phalangeal joints and the movement pattern must be constant length. In contrast, the range of motion of the proximal and distal inter-phalangeal joints may be allowed to change, this requires respond a specific stimulus by coordinating agonist and antagonist muscles. This ability demands a long training period of archer. The muscle-contraction strategy between forearm muscles and pull finger is defined as response to clicker fall. Different type of contraction-relaxation strategy can be used in the drawing arm with success, as it may avoid causing a lateral deflection of the bowstring (9). The muscles increase until clicker fall especially in second period of aiming phase. Muscles relax rapidly after clicker fall due to releasing (21).

5.7 ALTERNATIVE HYPOTHESIS

The Alternative Hypothesis (H_{A-1}) is the electrical activity of the muscles analyzed in the task of shooting an arrow to the target does not have the same temporal pattern. H_{A-1} is supported by outcomes of this study in the questions 1) what is the coordination of the temporal pattern of the upper limb of the set of muscles of the archery athletes on the task to shoot an arrow? Electrical activity increases in anticipatory phase due to growth in muscle demand before the release arrow and decreases activity after clicker fall in CPA and M phase by reduction of demand after release arrow. Difference in electrical activity reported that electrical activity of the muscles analyzed in the task of shooting an arrow to the target does not have the same temporal pattern. The result confirms hypothesis of this study.

Archery competitions lasted hours requiring a great deal of shoots. Such a situation may provoke deterioration of mechanical performance of one or more muscles and not maintain longer the desired force level, it demands technique and motor strategy changes. This modification is probably very smooth; their effect may produce undesirable impact on arrow scores (26). Results found by Tinazci (2011) are varying during shot according to the analysis. Performance enhance when the muscular activity of m. Flexor and m. Deltoid muscles decreases one second after the clicker falls. The same authors found in individual analysis more details of the results, because the archers have different muscle strategies to increase performance. One archer decreased the muscle activity in m. Flexor Digitorum Superficialis, m. Trapezius and m. Extensor a second prior to the clicker fall (11). However, other archer increase activity in extensor muscles of the releasing hand a second prior to clicker fall.

To summarize the result, eleven of the twelve studied muscles increased muscular electrical activity before the arrow was released. Muscular electrical activity decreases after the arrow release. According to Santos, Kanekar and Aruin (2010), unpredictable disturbances no presents anticipatory activity of the trunk and leg muscles, but significant compensatory activation of muscles was observed. In contrast, predictable disturbance showed strong anticipatory activation in all the muscles and smaller compensatory activity of muscles after the disturbances (29,30). For Labanca et al. (2015) postural stability is obtained during voluntary movement by compensatory and anticipatory strategies destined at minimizing unpredictable and predictable disturbance, respectively (63). In other words, larger compensatory reactions were seen during the unpredictable disturbances because these conditions were not associated with any anticipatory corrections (29,30,62,63). While dealing with disturbance, the general rule applied by the CNS is to optimally use anticipatory corrections if and when possible, resulting in appropriate decreases compensatory activity. During disturbance, the CNS uses anticipatory corrections if and when possible, resulting in reduced of compensatory activity. In addition, CPA is a mechanism of restoration of the position of the COM after a disturbance has happened (29,30), while APA reduce the effect of the forthcoming body disturbance with anticipatory corrections (29,30,62). APA not rule out the existence of a CPA-based posture control that involves online corrections and braking activities (29,30). One of the ways in injury prevention is the capacity to reduce postural disturbances in sports (63). The results of this study agree with studies described above since expected disturbance showed an increase in muscular activity before release arrow.

In the same way, largest APA1 response happen during 50ms before and 50ms after clicker fall for m. Flexor Digitorum Superficialis, m. Extensor Digitorum, m. Triceps Brachii, m. Rectus Abdominis Anterior, m. Serratus Anterior pull string, m. Latissimus Dorsi, m. Upper Trapezius, m. Serratus Anterior stabilizes the bow and m. Posterior Deltoid. Two muscles (m. Biceps Brachii Long Head and m. Pectoralis Major Clavicular Head) presents largest APA during APA1 (50ms before and after clicker fall) and APA2 (50ms to 150ms before clicker fall). Other studies showed that predictable disturbance, the largest anticipatory responses occurred during -100ms and +50ms in relation to T0. This outcome involves APA in movement self-initiated (29,30,116) or external predictable disturbance (2). This outcome suggests that largest APA imply that CNS is capable of generating APA in a time frame that is close to moment of disturbance in this case release arrow.

CPA1 (50ms to 150ms after clicker fall) had a higher response when than CPA2 and CPA3 for m. Extensor Digitorum, m. Biceps Brachii Long Head, m. Triceps Brachii, m. Serratus Anterior pull string, m. Upper Trapezius. Fortified by this result, Santos, Kanekar and Aruin (2010) described that largest CPA responses were seen during the first phase from 50ms to 150ms after the disturbance onset in almost all studied muscles. The authors add that the body disturbance were minimized with the success of muscular responses generated right after the disturbance, resulting a smaller CPA in second phase, stabilization (CPA2) phase of the compensatory control of posture (29). In contrast, m. Pectoralis Major Clavicular Head presents largest CPA1 when compared with CPA3. Santos, Kanekar and Aruin (2010) suggest that the larger CPA can generate ‘‘too much” compensation which needs to be corrected observed during CPA2 (29,30). These results showed that largest CPA implies that CNS is capable of generating CPA later to moment of the disturbance, in this case after the release arrow.

5.8 Study limitations

In respecting the limitations of study about the experimental design, the EMG procedure, climatic conditions, training place, choice of outdoor archery. Limitations are discussed below.

Data collection in training place of archers might increase the ecological validity of this study. Data was collected in an outdoor manner, as it may be that the results are influenced by climatic conditions. The collection occurred in sunny and cloudy weather. It did not always have the same climatic conditions for all archers. However, it was not collected on rainy days.

Archers were recruited at the training center they were accustomed to training. If they travel to the laboratory it would be 2 hours of displacement that could change the rhythm of the archer. In this case, the researchers traveled to the training center to collect the data. In addition, the outdoor archery would not be possible in the laboratory, because needs 70 meters distance between the archers and the target. Hence, dimensions of our laboratory do not allow such experimental design. We would not have performed the Olympic simulation in laboratory.

Callaway, Wiedlack and Heller (2016) related the practical application problem in studies. Previous studies looking at EMG has been useful to the sport by allowing scientists to better understand some motor control patterns involved in the shot sequence (25). However, we know that transfer of science into practical terms can often take a while or be poor.

Lin et al. (2010) indicate the importance limitations general to the use of surface electrodes should also be noted. Potential difficulties with surface EMG recordings include crosstalk (especially in the forearm muscles), between closely spaced electrode pairs and artifacts arising from movement. The positions of the electrodes, check of signal quality, and the tests selected for the humeral and scapular muscles reduce crosstalk possibility (51). Other studies used the same method as a way of capturing muscular activity in archery.

Stuart and Atha (1990) demonstrated other problem that is applied in this study. Small sample size limits the study. However, criterion values are designed to take sample size into account, and there are no hints from the data that an increased sample size would have changed any decisions (54). But, the target public is Brazilian Team which contained 10 archers at the time the research was carried out. This was because the goal was to analyze successful strategies in archery. Heller (2012) described that general interpretation of results in performance context analysis is problematic due to small sample size, which is a common problem in the analysis of elite athletes. Archer with unfavorable values can change predictability dramatically (27).

Nevertheless, previous studies were not able to clarify contraction and relaxation strategy of the forearm muscles used by archers because it is not clean the reason for use of more than one strategy observed in the same group. Several studies measured the forearm muscles and the muscle activity (17). Studies related low back and glenohumeral joint muscles are limited number and they have reported limited explanations of the muscular activities (21). Previous studies had different objectives than this study; it was difficult to compare the results with studies of other researchers.

6 CONCLUSION

The main of the study was analyzing electrical activity of archers to shoot an arrow from the bow. Hypothesis Alternative was confirmed, the electrical activity analyzed in the task of shooting an arrow to the target have different temporal pattern in Anticipatory Postural Adjustments (APA), Compensatory Postural Adjustments (CPA) and Modulation (M).

All muscles (except the m. Lumbar Multifidus) were more active in the interval near clicker fall in the APA due to increase demand with the proximity of arrow release. In interval of CPA, m. Extensor Digitorum, m. Biceps Brachii Long Head, m. Triceps Brachii, m. Pectoralis Major Clavicular Head, m. Serratil Anterior pull string and m. Upper Trapezius decreases activity after clicker fall. M phase of m. Extensor Digitorum, m. Biceps Brachii Long Head, m. Triceps Brachii decreased their activity after clicker fall. Decrease in CPA and M phase can be due to reduced demand for muscle after clicker fall.

Comparison between blocks of 6-arrows and APA showed that m. Flexor Digitorum Superficialis, m. Triceps Brachii, m. Rectus Abdominis Anterior, m. Serratil Anterior pull string, m. Lumbar Multifidus, m. Latissimus Dorsi and m. Upper Trapezius were affected by blocks of 6-arrows because its demand change in electrical activity before clicker fall. In CPA, m. Triceps Brachii, m. Rectus Abdominis Anterior, m. Lumbar Multifidus and m. Latissimus Dorsi were affected by the blocks of shots during the CPA. However, the M intervals of m. Biceps Brachii Long Head, m. Triceps Brachii, m. Serratus Anterior stabilizes the bow, m. Lumbar Multifidus and m. Latissimus Dorsi were affected by blocks of 6-arrows due to postural demand change throughout this phase. There are 3 ways in comparison of phases and the blocks: 1) affected by phases and affected by all/any phases in the blocks of 6-arrows, 2) affected by phases and unaffected by all/any phases in the blocks of 6-arrows and 3) unaffected by phases and affected by all phase in the blocks of 6-arrows.

Motor muscles were strong correlation among them, but the forearm muscles obtained inverse relationship between them. Postural muscles m. Lumbar Multifidus, m. Latissimus Dorsi, m. Upper Trapezius were strong correlation with all postural muscles. M. Serratus Anterior pull string was not strong correlation with m. Rectus Abdominis Anterior. M. Serratus Anterior stabilizes the bow was not strong correlation with m. Rectus Abdominis Anterior and m. Latissimus Dorsi. M. Flexor Digitorum Superficialis was strong correlation with m. Rectus

Abdominis Anterior, m. Latissimus Dorsi and m. Upper Trapezius. M. Extensor Digitorum was strong correlation with m. Serratus Anterior pull string. M. Biceps Brachii Long Head was not strong correlation only with m. Rectus Abdominis Anterior. M. Triceps Brachii, m. Pectoralis Major Clavicular Head and m. Posterior Deltoid were strong correlation with all postural muscles.

Generally, prior to clicker fall muscle activity increases due to the growth in muscle demand before the release arrow. After clicker fall, muscle activity decreases by reduction of the demand after release arrow. Some muscles were not affected by the intervals of the APA, CPA and M. This is related by maintenance electrical activity across intervals by similar muscular demand. The different outcomes of the electrical activity of the muscles shows that each archer performs different strategies to accomplish the same task: to throw the arrow in the middle of the target. Archers can permeate several paths to achieve the same result: release arrow in target.

7 SUGGESTIONS FOR FUTURE RESEARCH

Future studies could enhance this same experimental design to compare archers of elite, middle, beginners and non-archers. For Ertan (2009) this comparison could assist for assessing shooting techniques, evaluation of progress and talent selection. It is indicating that EMG can indicate the level of progression of archers. In addition, a study that evaluates archers over time to compare the variables and the progression pattern over time (10).

For Callaway, Wiedlack and Heller (2016), despite the history of archery, the majority of our present understanding and its mechanics have been derived from empirical observations made by coaches and athletes. To fill this dearth, studies develop the scientific cognizance of various technique aspects of archery, which has generally been demonstrated through EMG investigations. The use of EMG over time for accompanies progression of archers. The inclusion of EMG in performance routines demonstrate control of rhythm within the shots. This should lead coaches to focus on the rhythm-focused interventions rather than component-specific interventions which would be a significant asset to the athlete (25).

Score in target is a combination of other analysis and variables. Ertan (2013) described that recorded scores are typically written on a sheet of paper, with some elite competitions using a computerized score entry pad, where each end (block) of arrows shot are recorded in the order of highest to lowest value and added for a cumulative total, effectively a form of frequency table. In addition, the individual analysis of each archer may be according as the skill level of the archer, compare other distances between archer and target, modify the number of shots (38). Few of them describe influence of the equipment on subject’s skill and physical capacities (5). With this parameter, future studies could verify temporal pattern in postural adjustment of archery.

Finally, future research could replicate the descriptive findings with other groups of archers before they are applied for either elite athlete screening or training programs. In addition, other closed-skill sports should be examined so a comparison of the different kinds of predictive variables can be made. The processes underlying these predictive factors in closed-skill sports should be explored so that more accurate descriptions of their effect on performance can be generated (101).

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APPENDIX A - TERM OF CONSENT

UNIVERSIDADE DE SÃO PAULO
ESCOLA DE ARTES, CIÊNCIAS E HUMANIDADES
Comitê de Ética em Pesquisa em Seres Humanos

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

I - DADOS DE IDENTIFICAÇÃO DO SUJEITO DA PESQUISA OU RESPONSÁVEL LEGAL

1. DADOS DO INDIVÍDUO

Nome completo ______
Sexo ______
RG ______
Data de nascimento ______
Endereço completo ______
CEP ______
Fone ______
e-mail ______

2. RESPONSÁVEL LEGAL

Nome Completo ______
Natureza (grau de parentesco, tutor, curador, etc.) ______
Sexo ______
RG ______
Data de nascimento ______
Endereço completo ______
CEP ______
Fone ______
e-mail ______

II - DADOS SOBRE A PESQUISA CIENTÍFICA

1. Título do Projeto de Pesquisa: Sinergismo Muscular dos Membros Superiores e do Troncono Tiro com Arco
2. Pesquisador Responsável: Luis Mochizuki
3. Cargo/Função: Docente
4. Avaliação do risco da pesquisa: Risco Baixo *(probabilidade de sofrer algum dano como consequência imediata ou tardia do estudo)*
5. Duração da Pesquisa: 2 anos
6. Protocolo: Agência de Fomento e Número

III - EXPLICAÇÕES DO PESQUISADOR AO INDIVÍDUO OU SEU REPRESENTANTE LEGAL SOBRE A PESQUISA, DE FORMA CLARA E SIMPLES, CONSIGNANDO:

1. Este estudo tem como objetivo principal descrever a ação muscular de arqueiros durante o tiro. Os músculos foram escolhidos pela ativação durante os ajustes posturais, no lado dominante flexor radial do carpo (Fernando colocou flexor superficial dos dedos), extensor dos dedos, bíceps braquial porção longa, tríceps braquial, peitoral maior porção clavicular, reto abdominal porção anterior, serrátil anterior, multífido, latíssimo do dorso e trapézio superior; e do lado não dominante os músculos serrátil anterior e deltoide porção posterior. O maior conhecimento da ação destes músculos pode trazer a elaboração de estratégias para o desempenho esportivo.
2. O voluntário terá 12 canais e 25 eletrodos fixados ao seu corpo para a captação de sinais com eletromiografia, e 1 eletrodo terra. Todos os tiros serão gravados a fim de sincronizar a imagem com o aparelho de eletromiografia, e terá um acelerômetro acoplado ao seu punho para captar o início do movimento e preencherá um questionário da análise de satisfação e estratégia;
3. Não espera-se riscos ou desconfortos com esta pesquisa. Caso o voluntário tenha alguma intercorrência devido aos procedimentos do estudo, o mesmo deve comunicar ao pesquisador responsável;
4. A participação é voluntária, e o referido não receberá quaisquer benefícios em dinheiro ou benefícios de qualquer outro modo;
5. Para dirimir as dúvidas ou esclarecimentos relacionadas a pesquisa, basta entrar em contato, com o pesquisador responsável ou com o Conselho de Ética em Pesquisa em Seres Humanos da Escola de Artes, Ciências e Humanidades da Universidade de São Paulo.

IV - ESCLARECIMENTOS DADOS PELO PESQUISADOR SOBRE GARANTIAS DO SUJEITO DA PESQUISA:

1. Todos os experimentos serão realizados de forma não invasiva. Em qualquer etapa deste estudo você terá acesso aos profissionais responsáveis para esclarecimento de eventuais dúvidas;
2. Em caso de recusa você não será penalizado(a) de forma alguma. Além disso, você tem liberdade de retirar seu consentimento e deixar de participar do estudo a qualquer momento, sem que isto traga qualquer prejuízo;
3. Desde logo fica garantido a confidencialidade, sigilo e privacidade das informações, com os dados divulgados apenas em artigos e eventos científicos, garantindo o sigilo de identidade do sujeito da pesquisa;
4. Você receberá dos pesquisadores todo apoio e assistência e acompanhamento por eventuais danos à saúde, decorrentes da pesquisa.

V - INFORMAÇÕES DE NOMES, ENDEREÇOS E TELEFONES DOS RESPONSÁVEIS PELO ACOMPANHAMENTO DA PESQUISA, PARA CONTATO EM CASO DE INTERCORRÊNCIAS CLÍNICAS E REAÇÕES ADVERSAS.

Pesquisador Responsável: Dr. Luis Mochizuki
Endereço: Rua Arlindo Bettio, 1000. Sala 319D. Ermelino Matarazzo. CEP: 03828-080. São Paulo-SP.
Instituição: Escola de Artes, Ciências e Humanidades da Universidade de São Paulo
Telefones para contato: (11) 3091-8805
Pesquisadores gerentes: Fernando Reiser Carvalheiro (47) 9612.3559 – (11)983.484.135, Nadjila Tejo Machado (11) 985.224.450

VI - CONSENTIMENTO PÓS-ESCLARECIDO

Declaro que, após a leitura deste documento e esclarecer as minhas dúvidas conversar com o pesquisador responsável e estar ciente do protocolo, concordo em participar como voluntário do projeto de pesquisa supracitada. Estou ciente dos objetivos da pesquisa, dos procedimentos aos quais serei submetido, dos possíveis danos ou riscos deles provenientes e da garantia de confidencialidade e esclarecimentos sempre que desejar. Diante do exposto expresso minha concordância de espontânea vontade em participar deste estudo.

São Paulo, _____/_____/_____

assinatura do sujeito da pesquisa ou responsável legal	assinatura do pesquisador (carimbo ou nome legível)

Pesquisador Responsável:
Luis Mochizuki – mochi@usp.br

Discentes: Fernando Carvalheiro Reiser – ray.reiser@gmail.com
Nadjila Tejo Machado – nadjila@folha.com.br

APPENDIX B – GRAPH

Figure 7 - Mean and standard deviation (SD) RMS of muscles during anticipatory postural adjustment (APA) and compensatory postural adjustment (CPA)

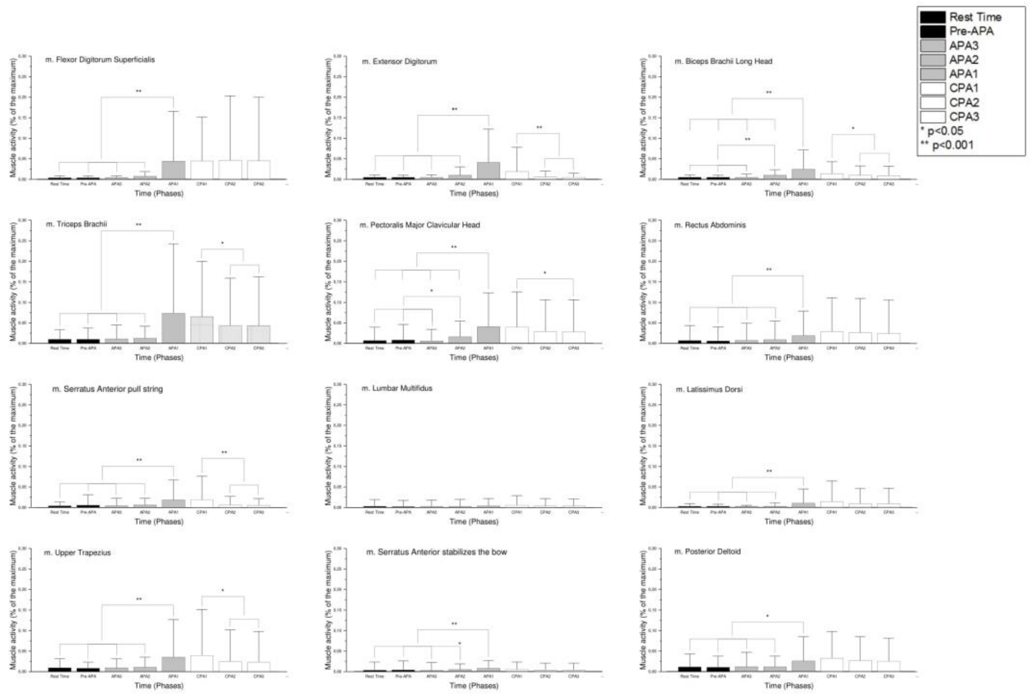
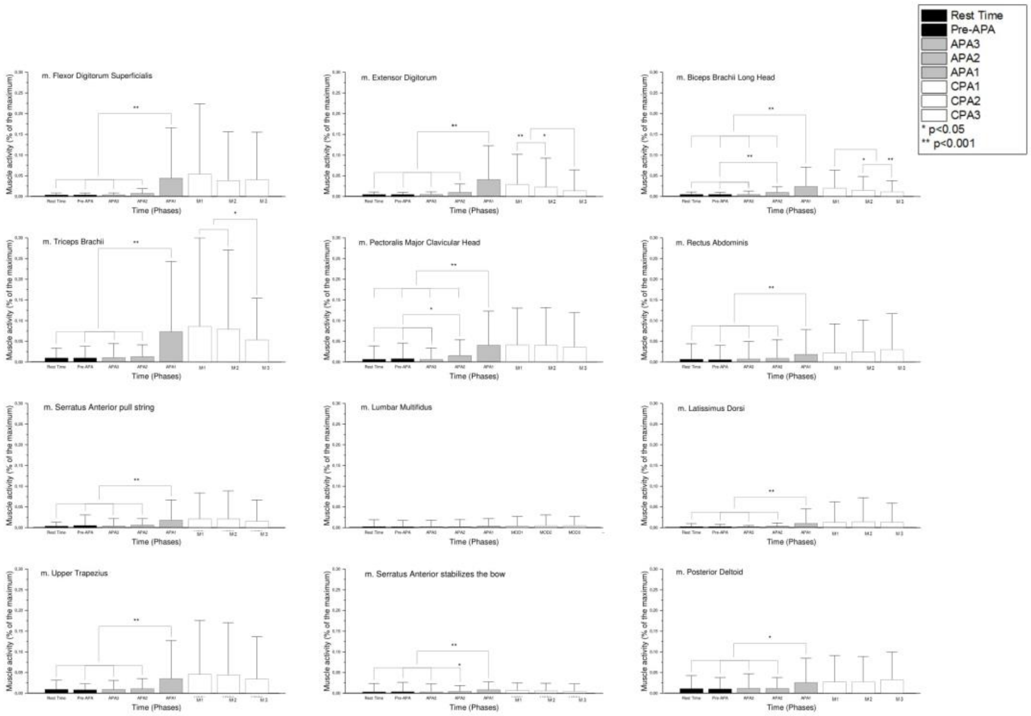


Figure 8 - Mean and standard deviation (SD) RMS of muscles during APA and modulation (M)



APPENDIX C - ANATOMY UPPER LIMBS AND TRUNK

Archery is described as a static sport requiring strength and endurance of the upper body, in particular the shoulder girdle (7,17,49). Due to the muscular demand for accomplishment of the movement in the archery, as well as the data measurement of this study by EMG and the electrode position recommendation. Therefore, the first part of the appendix in this literature review is about anatomy of upper limbs and trunk. Anatomy is the study of the structure of the human body (97) and humans have the capacity to produce a variety of postures and movements that require the structures of human body to both generate and respond to forces that produce and control movement at the body's joints (103). Description of movements can be difficult because various parts of the body can produce movement in many different directions often more than one joint is involved (117), but the analysis of the complex of body human by means of movement patterns of individuals for in search of the best performance in the sport (118). It is very important understand anatomy because helping to knowledge the interaction of trunk, scapular and humeral motion provides a dynamic linked system that is used in many ways in numerous sports activities, from providing a stable base for archery promoting a very mobile by scapula allows the glenohumeral joint to be most mobile joint in the human body (119).

The objective of this part of literature review is described the anatomy of shoulder, elbow, wrist, trunk and spine from the point of view of bone, joints, ligaments, movements and degrees of motion in the macroscopic structures. The detailing of the parts of the shoulder, elbow, wrist, and trunk were due to the choice of the muscles for the position of the electrodes in the detection of muscular electrical activity. Muscles are specifically described in the part of the "APPENDIX D - MUSCLES ANALYZED: ORIGIN, INSERTION, ACTION, ELECTRODE POSITION", because in this part there is more detail of the origin, insertion and action of the muscles analyzed in this study (m. Flexors Digitorum, m. Extensor Digitorum, m. Biceps Brachii Long Head, Triceps Brachii, m. Pectoralis Major Clavicular Head, m. Rectus Abdominis Anterior, m. Serratus Anterior, m. Lumbar Multifidus, m. Latissimus Dorsi, m. Trapezius Upper, m. Serratus Anterior and m. Posterior Deltoid).

Shoulder

Bones promote levers for movement and are adapted to withstand stress and this system allows movement in the body (120). Upper limbs are composed by the bones: clavicle, scapula, humerus, radius, ulna (united largely by the interosseous membrane) and bones of the hand: carpals, metacarpals and phalanges (121). But, the shoulder complex is composed only for three bones: clavicle, scapula and humerus that are intricately designed combination of three joints that connect the upper extremity to the thorax (103). Joint center of rotation of shoulder is situated at the center of the head of the humerus (119). Kapandji (2000) described five joints separated for two groups, the first group: scapulohumeral and subdeltoid joints, the second group: scapulothoracic, sternoclavicular and acromioclavicular joints (106). Any authors report that the function of shoulder is integrated motion of the sternoclavicular, acromioclavicular, glenohumeral and scapulothoracic joints (103,122,123). Rhythm scapulohumeral during the initial 60º of flexion or the initial 30º of abduction of the humerus, an inconsistent amount and type or scapular motion occurred in relation to glenohumeral motion. The scapula seeks a position of stability in relation to the humerus during this period, call of setting phase (103).

Zatsiorsky (1998) describe a set of angles describe anatomical angles by joint angle. For the majority of joints, the recommended sequence of Cardan's angles is 1) flexion-extension, 2) abduction-adduction, and 3) axial rotation. For the shoulder joint, the following sequence of the Euler's angles is advised: 1) rotation around the trunk-fixed vertical axis, which determines the plane of arm elevation; 2) arm elevation in the predefined plane; and 3) axial rotation. The helical method does not provide clinical representation of three-dimensional joint motion (124).

Shoulder is the most mobile joint of the body human with three degrees of freedom: classically flexion (45º-50º degrees) and extension (180º degrees), abduction (180º degrees) and adduction (maximum adduction in the anatomical position), medial (100-110º degrees) and lateral (80º degrees) rotation. Circunduccion shoulder combined the three degrees of freedom (106). Amplitude of motion may vary according to the individual. However, the same author, describe other movement: anteposition or retroposition of the stump shoulder, flexion and extension horizontal of the shoulder and circunduccion of shoulder. Codman's paradox, according to Kapandji (2000) (106) and Rockwood, Matsen III (2004) (122), is observed from the resting position in anatomical posture, when performing 180° abduction movement followed by 180° extension movement, the position of the upper limb is returned vertical along body, but with the palm of the hand turned outward and the thumb back. The contrary is true, the 180° flexion and 180° adduction.

Body human has approximately 50 named bursae, one of them is located on the shoulder complex (122). Bursae is an enclosed sac lined with synovial membrane and containing synovial fluid (120), and enables structures that are subjected to friction to function (103,120) can facilitate the motion of structure. Several bursae are associated with the shoulder complex in general and with the glenohumeral joint principally (103). The subacromial and subdeltoid bursae contributed to function of shoulder (103,122), the bursae serve to lubricate motion between the rotator cuff and the overlying acromion and acromioclavicular joints (122), and separate the supraspinatus tendon and head of the humerus from the acromion, coracoid process, coracoacromial ligament and m. Deltoid (103). Bursae have hollow spaces, for dissection because they are the most complete of the lubricating spaces, they are encountered between the most unylelding tissues: between tendon and bone or skin and bone and occasionally between muscle and bone near a tendon insertion (122).

Elbow

Joint center of elbow is located at the midway along that line of rotation (119). Elbow has three bones (humerus, radius and ulna) and only 1 joint and articular cavity (106). Bony structure provides about half of the elbow’s stability, with the remaining stability provided by the joint capsule and the ulnar and radial ligament complexes (123). The elbow is an intermediate joint of the upper limb: by performing the mechanical union between the first segment - the arm - and the second - the forearm - of the upper limb (106). Elbow complex includes the elbow joint (humero ulnar and humeroradial joints) and the proximal and distal radioulnar joints (103,123). Humeroulnar joint, in ovular trochlea of humerus is articulate with the reciprocally shaped trochlear fossa of the ulna. Humeroradial joint is formed between the spherical capitellum of the humerus and the proximal end of the radius. Proximal radioulnar joint are annular ligament binds the head of the radius to the radial notch of the ulna (123).

One can distinguish two different functions for the elbow: flexion-extension and pronation-supination (106). A number of factors determine the amount of motion that is available at the elbow joint. These factors include the type of motion (active or passive), the position of the forearm (relative pronation-supination), body mass index, and the position of the shoulder. The body mass index is controversial because the indicating overweight has been identified as a factor limiting elbow range of motion (103). The flexion and extension of elbow used humeroulnar and humeroradial joints, while the pronation and supination involve the superior radioulnar joint. Active flexion reaches 145º and the passive at 160º, extension is limited by the olecranon, tension of joint capsule and resistance of the flexor muscles (106).

The proximal and distal radioulnar joints acting together produce rotation of the forearm and have 1 degree of freedom of motion. The radioulnar joints are diarthrodial uniaxial joints of the pivot (trochoid) type and permit rotation (supination and pronation). Elbow joint and the proximal radioulnar joint are enclosed in a single joint capsule, but constitute distinct joints (103,123), and this joint is reinforced by the anterior and posterior radial collateral and ulnar collateral ligaments (123). Most hinge joints in the body have collateral ligaments, and the elbow is no exception. Collateral ligaments are located on medial and lateral sides of hinge joints to provide medial/lateral stability and to keep joint surfaces in apposition. The two main ligaments associated with elbow joints are the medial (ulnar) and lateral (radial) collateral ligaments (103).

Joint capsule is a structure encloses the joint, prevents loss of fluid, and binds together the ends of the articulating bones. Outer layer of the capsule is composed of dense connective tissue and represents a continuation of the periosteum. Fibers of the outer capsule have predominance of parallel bundles (called ligaments) to reinforce joints and prevent unwanted movement. The interior of the capsule is covered by a synovial membrane, which covers the deep surface of the capsule and folds over at the capsular insertions. Its principal function is to secrete synovial fluid in the articular cavity. This fluid lubricates the joint and provides nutrients to the cartilage (117). In elbow, humeroulnar, humeroradial, and superior radioulnar joints are enclosed in a single joint capsule. Capsule is fairly large, loose, and weak interiorly and posterior and it contains folds that are able to expand to allow for a full range of elbow motion (103).

Wrist

The hand is located at the extremity of the upper body and is due to the enormous mobility of the fingers, which are equipped with a complex system of tendons (117). Wrist consists of two compound joints: the radiocarpal and the midcarpal joints, referred as the wrist complex (103). Joint center of wrist is localized at the midway along that line of rotation (119). The wrist is composed of radiocarpal and intercarpal joints (123) and other author described as midcarpal and radiocarpal joints (103,106). Radiocarpal joint articulates the antebrachial glenoid with the carpeal condyle; now, midcarpal joint articulates between them the two rows of carpal bones (106). Most wrist motion occurs at the radiocarpal joint, a condyloid joint where the radius articulates with the scaphoid, the lunate, and the triquetrum (123). The radiocarpal joint is composed of the radius and the radioulnar disc, with the scaphoid, lunate, and triquetrum (or triquetral). The midcarpal joint is composed by scaphoid, lunate, and triquetrum with the trapezium, trapezoid, capitate, and hamate (103,123), as well as the bones metacarpals and phalanges (123). The wrist consists of two rows, each containing four bones and metacarpal form the skeleton of the palm and too if connected with phalanges. Ligaments are dense bundles of parallel collagenous fibers, these are often derived from outer layer of the joint capsule but may also connect nearby but non-articulating bones. Ligaments function chiefly to strengthen and stabilize joint in a passive form, except for a few ligaments which contain a high proportion of yellow elastic fibers that can they stretch (28).

Many joints are required to provide the extensive motion capabilities of the hand , for example: carpometacarpal, intermetacarpal, metacarpophalangeal and interphalangeal. The fingers are referred to as digits one through five, with the first digit being the thumb (123). The wrist complex as a whole is considered biaxial, with motions of extension-flexion and ulnar/radial deviation (103,123). Some investigators argue that some degree of pronation-supination may also be found, especially at the radiocarpal joint (103). Amplitude of flexion and extension are 85º (103,106) and 90º, 15° of radial deviation (106) and other author arrives to 21º (103), and 45° of ulnar deviation (103,106). Circumduction movement is defined as combination of flexion-extension movements with adduction-abduction movements in wrist (106).

The fingers movement allow flexion and extension, and in some individuals, slightly per extension. Distal interphalangeal joints go from approximately 12° to 31° of flexion, and the proximal joints go from about 19° to 70° of flexion. Thumb movements are: abduction, hyperadduction, extension, flexion, hyperflexion and opposition (123). The thumb has a specific orientation vis-à-vis the rest of the hand (117), thumb occupies a position and performs the function separately from the hand because it is indispensable to make the forceps for each of the other fingers, and also for the constitution of a grip of force with the other four fingers and too manual grip. Canal so participate in actions associated with holdings that refer to the hand itself. Without the thumb, the hand loses most of its capabilities (106). Motions at the radiocarpal and midcarpal joints are caused by a rather unique combination of active muscular and passive ligamentous and joint reaction forces. Although there are abundant passive forces on the proximal carpal row, no muscular forces are applied directly to the proximal row, given that the flexor carpi ulnaris muscle applies its force via the pisiform to the more distal bones. The proximal carpals are effectively a mechanical link between the radius and the distal carpals and metacarpals to which the muscular forces are actually applied (103).

Thorax and Spine

The trunk is the central part of the body (117) and the pelvic girdle forms the base of the trunk. It also forms the support of the abdomen and forms the union between the lower limbs and the trunk (106). The thorax is formed for thoracic vertebrae, 12 pairs of ribs, sternum and costocartilages. The trunk serves a function, which is connected to its bony structure, the vertebral column (117), this structure provides a base for the muscle attachment of the upper extremities, the head and neck, the vertebral column, and the pelvis (103), protection for the heart, lungs, and viscera; other important function of the chest wall is its role in ventilation (103,106). The process of ventilation depends on the mobility of the bony rib thorax and the ability of the muscles of ventilation to move the thorax. The sternum is an osseous protective plate for the heart and is composed of the manubrium, body, and xiphoid process. Articulations that join the bones of the rib cage include the manubriosternal, xiphisternal, costovertebral, costotransverse, costochondral, chondrosternal, and the interchondral joints (103). Spine is the central pillar of the trunk (106).

The trunk can perform the following movements: flexion (anteriorly), extension (posteriorly), lateral flexion or side bending (laterally), rotation on its own axis. Range of movement varies depending on vertebral level due to several factors shape of the vertebrae, thickness of intervertebral discs (the thicker the disc, the greater the mobility) and the thoracic vertebrae articulate with ribs, which limit mobility (117). When the trunk is flexed, the first 50–60° of motion occurs in the lumbar spine and adds motion resulting from anterior pelvic tilt (123). The spine forms a mobile bony stem which constitutes a part of the skeleton of the trunk (117).

The spine is the axis of the body and must reconcile two contradictory mechanical: rigidity and flexibility (106). Spine is a complex and functionally significant segment of the human body (123). Providing the mechanical linkage between the upper and lower extremities, the spine enables motion in all three planes, yet still functions as a bony protector of the delicate spinal cord (103,106,123) and trunk support (103,106). The vertebral column resembles a curved rod, composed of 33 vertebrae and 23 intervertebral discs (103). The spine consists of a curved stack of vertebrae divided structurally into five regions are: cervical (7 vertebrae), thoracic (12 vertebrae), lumbar (5 vertebrae), fused sacral (5 vertebrae), and fused coccygeal (4 small vertebrae) (103,123). Each vertebra consists of two main parts: the massive body in anterior part, and the vertebral arch in posterior part (117).

There may be one extra vertebra or one less, particularly in the lumbar region (103,123). Six main ligaments are associated with the intervertebral and zygapophyseal joints. They are the anterior and posterior longitudinal ligaments, the ligamentum flavum, and the interspinous, supraspinous, and intertransverse ligaments (103), these ligaments extending the length of the vertebral column. Surfaces of the articular processes are linked together through a capsule insetted on its circumference. The inside of this capsule is reinforced by an extension of the ligamentum flavum and, at the back, by a posterior ligament (117). Vertebral column is an amazingly complex structure that must meet the seemingly demands of mobility and stability for the trunk and the extremities of body (103).

The column has three degrees of freedom: flexion-extension, lateral tilt to the left and right, and axial rotation. In the lumbar spine the flexion is until 60° and the extension is of 35°; dorsolumbar column the flexion is of 105° and the extension is of 60°; cervical spine the flexion is of 40° and the extension is until 75°. Total flexion of the spine is of 110° and the total extension is 140°. Lateral inclination of the lumbar spine is 20°, the dorsal spine is 20° and the cervical spine is 35-45°. Total inclination of the spine between the sacrum and the cranium is then 75-85°. Axial rotation in the dorsal spine is 35°, this is favored by the arrangement of the articular apophyses. Axial rotation in the cervical spine is of 45 to 50°. Atlas rotates approximately 90° in relation to the sacrum. Axial rotation between the pelvis and the cranium is until 90°. In fact, there are some degrees of axial rotation in the atlanto-occipital, but as axial rotation is often smaller in the dorsolumbar spine, the total rotation arrives to 90° (106).

APPENDIX D - MUSCLES ANALYZED: ORIGIN, INSERTION, ACTION, ELECTRODE POSITION

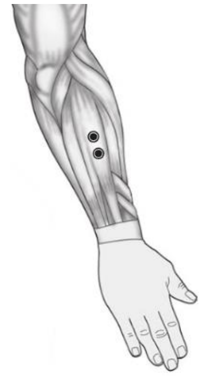
The electrodes fixed followed the guidelines outlined below:

Figure 9 - Electrode placement for m. Flexor Digitorum Superficialis

Source: Adapted from Cram; Kasman and Holtz (2011) (125).

For beginning electrode position, the palpation was in first muscle between the middle line in middle forearm (126). According to recommendation, support the arm as occurs palpation with pinkie on the medial side of the forearm, about 2% of the distance from the elbow to the handle. Individual diverts hand toward the pinkie. Insertion of electrodes on a palpable muscle mass occurs in the direction of the muscle fibers, on which, the two electrodes are arranged to 2cm distance between them (95). M. Flexor Digitorum Superficialis has three origins: humeral portion in common flexor tendon from medial epicondyle of the humerus, ulnar collateral ligament of elbow joint, and deep antebrachial fascia, ulnar portion on medial side of the coronoid process; and the radial portion in the oblique line of radio. The insertion is by four tendons on the sides of the intermediate phalanges of the second to the fifth finger (127). Its action is to flexion the proximal interphalangeal joints of the second to the fifth finger, assists in flexing the metacarpophalangeal joints and flexion of the handle (95,126,127). M. Flexor Digitorum Superficialis perform flexion of the middle phalanges of each finger can also assist in flexing the handle. With action this muscle, can hold an object with the hand shaped hook, using seizure force each in archery (107).

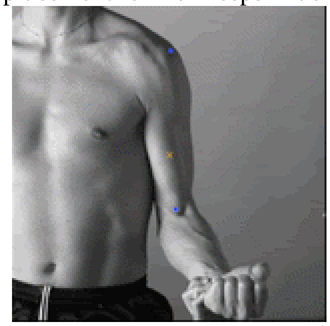
Figure 10 - Electrode placement for m. Extensor Digitorum



Source: Adapted from Cram; Kasman and Holtz (2011) (125).

Electrode position for m. Extensor Digitorum starting with palpation, the palpation in the middle of forearm about three quarters of the distance between the elbow and the handle of the subject, while the fingers are extended. The two electrodes are 2cm apart from each other (95). The electrode is inserted only in the superficial part of the muscle (126). Origin of m. Extensor Digitorum is in common extensor tendon by lateral epicondyle of the humerus and of antebrachial fascia profunda. Insertion is located in four tendons, each penetrating a membranous expansion in dorse of the second to the fifth finger and if divided over the proximal phalanges in the medial band of two laterals. Medial band inserts into the base of the intermediate phalanges, while the lateral bands again attach to the intermediate phalanges and are inserted into the base of the distal phalanges. M. Extensor Digitorum has the action of extending the metacarpophalangeal joint and, in conjunction with m. Lumbrical and m. Interosseous, extends the interphalangeal joints from the second to the fifth finger. Helps in the abduction of the forefinger, annular and minimum fingers; assists in the extension and abduction of the handle (127). The action of m. Extensor Digitorum only as the extension of the fingers (95). The action of m. Extensor Digitorum how the extension of the second to the fifth finger (126). M. Extensor Digitorum has the action the extension of finger, assists in abduction of finger moving away from the middle finger. This muscle loose objects hold with the fingers of the hands (107).

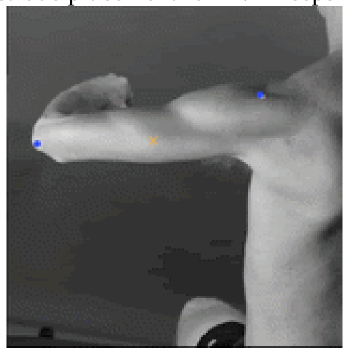
Figure 11 - Electrode placement for m. Biceps Brachii Long Head



Source: Adapted from Seniam (1999) (100).

The position of the electrode for m. Biceps Brachii should have followed the following standard: the individual flexes the forearm in the supinated position, palpation occurs in the muscular mass on the dorsal side of the arm (95). The electrodes are inserted in the line between the acromion and the cubital fossa, in the medial line between the acromion and the cubital fossa, with distance of 1/3 from the cubital fossa (100), in parallel the muscle belly, approaching biceps from its lateral side (126). The more lateral fixation of electrodes emphasize the detection of shoulder flexion (besides the flexion of the forearm), electrodes positioned most medially detect adduction and internal rotation, electrodes inserted distally with the lateral positioning have a certain volume of conduction from the brachial (95). M. Biceps Brachii has two origins: long head in the supraglenoid tubercle of the scapula, short head at the apex of the coracoid process of the scapula. The insertion is in the tuberosity of the radius and aponeurosis of m. Biceps Brachii (aponeurosis bicipitalis or lacertus fibrosus). Its action is to flexion the shoulder joint, and the long head may assist with abduction if the humerus is laterally rotated. The origin fixed, flexes the elbow joint by moving the forearm in the sense of humerus and supine the forearm. The fixed insertion, flexes the elbow joint by moving the humerus towards the forearm as in barbell exercises (127). Action of m. Biceps Brachii is the flexion of the forearm, supination and flexion of the shoulder (95). M. Biceps Brachii has the action flexion of elbow with the forearm in supination (126). M. Biceps Brachii performs flexion of the elbow joint and supination of the forearm, produces slight flexion of the arm at the shoulder joint, this muscle assists in lifting an object (107). M. Biceps Brachii is the main flexor of the elbow, and its secondary action is supination (106).

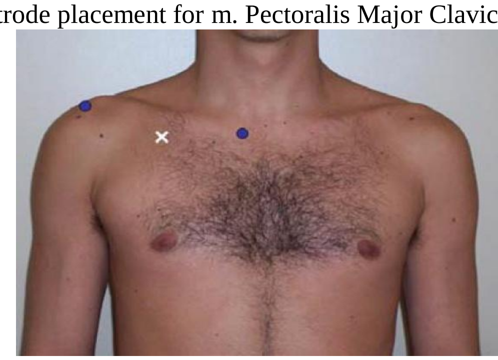
Figure 12 - Electrode placement for m. Triceps Brachii



Source: Adapted from Seniam (1999) (100).

Electrode position of m. Triceps Brachii is in middle line between the posterior crest of the acromion on the shoulder and the olecranon at the elbow, 2 fingers laterally to this line, being 2cm apart (100), the muscle belly is palpated during isometric contraction (95). Origins of m. Triceps Brachii are: long head in the infraglenoid tubercle in the scapula, lateral head on the lateral and posterior surface of the proximal half of the humerus and lateral intermuscular septum, medial head is located two-thirds distal from the medial and posterior surfaces of the humerus below the radial sulcus and medial intermuscular septum. The insertion lies on the posterior surface of the olecranon process of the ulna and antebrachial fascia (127). The action of this muscle is to extend the elbow joint. In addition, long head assists in the adduction and extension of the shoulder joint (95,127). Action of the lateral and long head, in which the action is of extension of the elbow (126). M. Triceps Brachii perform extension of the joint, long head performs the adduction of the humerus and extends it from the flexed position; it stabilizes the shoulder joint. This muscle assists in the throw movement (107).

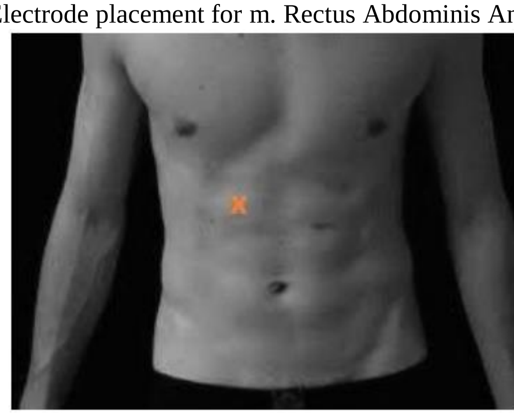
Figure 13 - Electrode placement for m. Pectoralis Major Clavicular Head



Source: Adapted from Tucci (2007) (128).

Electrode position in m. Pectoralis Major Clavicular Head started by palpated and in its medial part the electrodes are inserted around 2cm below the collarbone, in the medial part to axillary fold (128). Two electrodes are for 2cm apart and are placed on the thoracic wall at an oblique angle toward the clavicle, 5cm below the line between the sternoclavicular joint and the humeral head in its proximal third. Palpation of abdominal wall locates the belly of muscular mass because it aims not to insert electrode in region with great concentration of adipose tissue (95). There are two origins for m. Pectoral Major, clavicular head are on the anterior surface of the sternal half of the clavicle, sternocostal portion originated on anterior surface of sternum, cartilage of first six or seven ribs and aponeurosis of the sternal oblique. Insertion is at the crest of the greater tubercle of the humerus. Upper fibers are more anterior and caudal at the crest that the inferior fibers, which twist on themselves. Action of m. Pectoralis Major Clavicular Head can be made up two parts: 1) action of the muscle as a whole and the 2) action of the upper fibers. The muscle as a whole in the movement with the fixed origin adduction and rotates the humerus medially. Now, insertion fixed, m. Pectoralis Major can aid in the elevation of the thorax, as in forced inspiration. Superior fibers flex and rotate medially the shoulder joint and adduction horizontally the humerus towards the opposite shoulder (127). The muscle performs arm adduction (126). M. Pectoralis Major has the action of medial (internal) rotation and shoulder flexion; horizontal adduction of the arm and shoulder depression (95), adduction and medial rotation of humerus. Clavicular head flexes and makes the medial rotation of shoulder joint. Horizontally promotes adduction of humerus towards the opposite shoulder. The sternocostal part performs oblique adduction of the humerus towards the opposite hip joint (107).

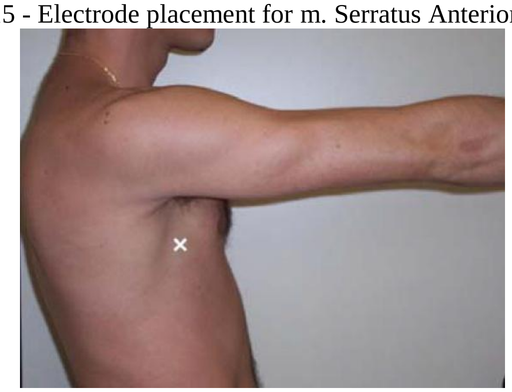
Figure 14 - Electrode placement for m. Rectus Abdominis Anterior



Source: Adapted from Cram; Kasman and Holtz (2011) (125).

The origin of m. Rectus Abdominis is located in the pubis and pubic symphysis; and the insertion is in the costal cartilages of the fifth, sixth and seventh ribs and xiphoid process of the sternum. The action of m. Rectus Abdominis is the flexion of the vertebral column approaching the thorax and pelvis previously. When the pelvis fixed the thorax move towards the pelvis; with thorax fixed the pelvis moving towards the thorax (127). Action of m. Rectus Abdominis is of flexion of the trunk and inclination of the pelvis (95), and flexes the lumbar portion of the cervical spine, lowers the thorax and stabilizes the pelvis during walking (107).

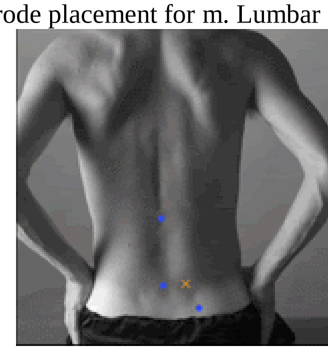
Figure 15 - Electrode placement for m. Serratus Anterior



Source: Adapted from Tucci (2007)(128).

Electrode position of m. Serratus Anterior starting with the palpation occurs in the flexion of the arm against the resistance in the anterior area for the lateral of m. Latissimus Dorsi at the level of the inferior border of the scapula. The electrode inserted horizontally are for 2cm apart (95) in the region below the armpit between the anterior border of m. Latissimus Dorsi and the posterior border of m. Pectoralis Major (128). In middle or anterior axillary line one should isolate a rib by placing two fingers on the spans, this spans must be anterior to m. Latissimus Dorsi, but posterior to the breast tissue in the woman (126). M. Serratus Anterior has its origin in the external surfaces and upper edges of the eight or nine upper ribs, if inserting into the costal surface of the medial border of the scapula. When the origin is fixed the muscle has as action the abduction of the scapula, rotates the lower angle laterally and the glenoid cavity and keeps the medial border of the scapula firmly against the thorax. In addition, the lower fibers can depress the scapula, and the upper fibers may raise it slightly. The scapula stabilized in adduction by m. Rhomboids, thereby securing the insertion, m. Serratus Anterior can act in forced inspiration (127). Other authors further describe scapular protraction during activities resistance such as pushing (95,126). M. Serratus Anterior has the action of upward (ascending) rotation, depression and abduction of the scapula during abduction and flexion of the arm (95). M. Serratus Anterior protrudes the scapula and promotes the rotation of the scapula for flexion and abduction of the arm. When leaning forward to achieve something, this muscle comes into action (107).

Figure 16 - Electrode placement for m. Lumbar Multifidus

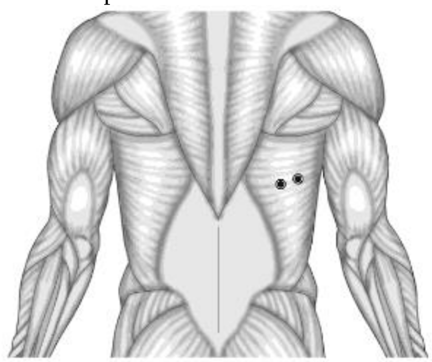


Source: Adapted from Seniam (1999) (100).

Electrode of m. Lumbar Multifidus are inserted into the caudal line of the posterior iliac spine at the upper end in the intermediate space between L1 and L2 space at the level of fifth lumbar spinous process, about 2-3 cm from the midline (100).

M. Multifidus originates in four regions: sacral, lumbar, thoracic and cervical. Sacral region has insertion in the posterior part of the sacrum, medial surface of the posterior-superior iliac spine and posterior sacroiliac ligaments. In the lumbar, the origin is in the transverse processes of fifth lumbar to fourth cervical. Already in the thoracic region the origin is in transverse processes of fifth lumbar to fourth cervical. Finally, in the cervical region the origin is in the transverse processes of fifth lumbar to fourth cervical. The insertion of m. Multifidus covering 2 to 4 vertebrae, inserted in the spinous process of a vertebra above (127). Thoracic region, m. Multifidus situated below some muscles paravertebrae. In the lumbar region m. Multifidus are covered by aponeurosis of m. Erector Spinae. The author further recommends the use of surface electrodes two centimeters laterally from the spinous process of the fourth lumbar. The bundles of the Mm are present up to 3cm laterally of the fourth lumbar. M. Multifids are the only muscle bundles found that cover the sacral vertebrae, the lumbosacral transition, and the lower lumbar vertebrae. On them is the aponeurosis of origin of m. Erector Spinae. M. Multifidus are considered the main responsible for intravertebral movements. Below of aponeurosis of origin of erector, the only contractile fibers that move and stabilize the lumbosacral transition and fourth lumbar/fifth lumbar are the fiber of m. Multifidus. In the lumbar region, especially in the inferior intervertebral joints, where they are the main posterior stabilizers, their muscular mass presents greater size (110). M. Multifidus acts in the cervical, in its action bilaterally, extension of the head and neck, already unilaterally the rotation to the opposite side of the head and neck (127). The action of m. Multifidus on the extension of the trunk (100). M. Multifidus (described as plural) protect the vertebral joints of movements produced by more powerful superficial agonist muscles; this muscle makes extension, lateral flexion and spinal rotation; help maintain posture and stability of the spine during movement (107).

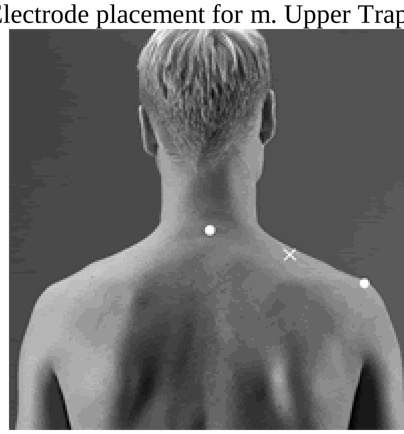
Figure 17 - Electrode placement for m. Latissimus Dorsi



Source: Adapted from Cram; Kasman and Holtz (2011) (125).

Electrodes of m. Latissimus Dorsi are set 2cm apart between them, in the posterior axillary part, directly lateral to the lower border of the scapula (126), approximately 4cm below the lower border of the scapula, half the distance between the spine and the lateral extremity of the trunk. In this area, the muscle fibers of m. Latissimus Dorsi are oriented at a slightly oblique angle of about 25 degrees (95). Origin of m. Latissimus Dorsi is in the spinous processes of the last six thoracic vertebrae, the last three or four ribs, by the thoracolumbar fascia from the lumbar and sacral vertebrae and posterior third of the external lip of the iliac crest, a strip from the lower angle of the scapula. The insertion of m. Latissimus Dorsi is located in the intertubercular groove of the humerus (127). The action of m. Latissimus Dorsi if the origin is fixed, to rotate medially, may also adduct and extend the shoulder joint. By continuous action, it depresses the shoulder girdle and helps in the lateral flexion of the trunk. The insertion fixed, it assists in tilting the pelvis anteriorly and laterally. Acting bilaterally, this muscle assists in spinal hyperextension and anterior pelvic tilt, or in the spinal flexion, depending on its relation with the axes of movement. M. Latissimus Dorsi can act as accessory muscle of the breath. M. Latissimus Dorsi rotates medially (internally), adducts and extends the shoulder/arm; participates in rotation, lateral flexion, and extension of trunk (95). M. Latissimus Dorsi performs extension and adduction of the humerus (126). M. Latissimus Dorsi extends the flexed arm and performs adduction and medial rotation of the humerus (carry the arm backwards toward in the body). This muscle helps in inspiration forced by elevation of lower ribs (119).

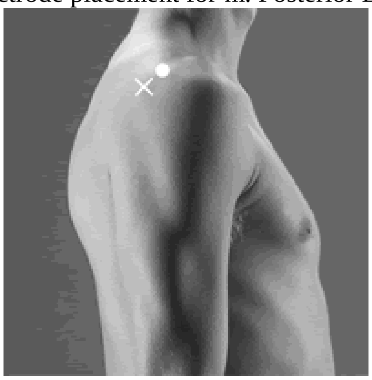
Figure 18 - Electrode placement for m. Upper Trapezius



Source: Adapted from Seniam (1999) (100).

To fix the electrodes to the skin, previously m. Upper Trapezius is palpated in the upper back in the area of the greatest muscle mass (95) the electrodes are fixed in the middle line of the acromion and the vertebra C7 (100), upper border of the shoulder and medial to the acromioclavicular joint. M. Upper Trapezius can be palpated between two fingers at this point (126). M. Trapezius has three origins: upper, middle and lower fibers. Upper fibers originate in the external occipital protuberance, medial third of the superior nuchal line, nuchal ligament and spinal process of the seventh cervical vertebra. Middle fibers originate in the spinous processes of the first to the fifth thoracic vertebra. Lower fibers have their origin in the spinous processes of the sixth to the twelfth thoracic vertebra. Insertion of m. Trapezius also has three fibers: upper, middle and lower. Upper fibers insert in the lateral third of the clavicle and acromion process of the scapula. Middle fibers have their insertion in the medial margin of the acromion and upper lip of the spine of the scapula. Lower fibers are inserted in the tubercle at the apex of the spine of the scapula. The action of m. Trapezius with the fixed origin is the adduction of the scapula, made mainly by the medium fibers with stabilization by the upper and lower fibers. Another action is to rotation of the scapula so that the glenoid cavity is directs cranially, made mainly by the upper and lower fibers with stabilization by the medium fibers. In addition, the upper fibers lift and the lower fibers depress the scapula. The insertion fixed, and acting unilaterally, the upper fibers extend, flexion laterally and rotate the head and joints of the cervical vertebrae in such a way that the face turns to the opposite side; acting bilaterally, m. Upper Trapezius extends the neck. M. Trapezius also acts as accessory muscle in respiration (127). The upper head has the action of adduction, upward rotation and elevation of the scapula; as well as lateral flexion of the head. The medial portion stabilizes the scapula; makes adduction, retraction and rotation upward (ascending) of the scapula during flexion and abduction of the arms, especially near its full movement. Lower portion also stabilizes scapula; upward rotation, retraction and depression of the scapula during abduction, flexion of the arms (95). Upper head accomplishes the elevation and "shrinking" of the shoulders and the middle portion accomplishes adduction of the scapula (126). The lower head of m. Trapezius elevates the shoulder joint, helps in preventing depression of the shoulder joint when a weight load on the shoulder and hands. Middle part of m. Trapezius promotes the retraction (adduction) of the scapula. M. Upper Trapezius promotes depression of the scapula, especially against resistance. Action of the upper and lower at the same time promotes the rotation of the scapula (107).

Figure 19 - Electrode placement for m. Posterior Deltoid



Source: Adapted from Seniam (1999) (100).

Electrode position of m. Posterior Deltoid begins by palpation on spine of scapula (95), electrodes should be centered about two fingers behind the acromion angle are 2cm apart between them, fixation in the skin in the direction of line between the acromion and little finger (100), at the midpoint of line connecting distal scapular spine and insertion of m. Deltoid (126), below the lateral border of the spine of the scapula at the oblique angle so that it is parallel to the muscle fibers (95). Classically m. Deltoid has three origins: anterior, medial and superior fibers. Anterior fibers origin from anterior border, upper surface of lateral third of clavicle. Medial fibers origin from lateral margin and superior surface of acromion. Posterior fiber origin from in lower lip by posterior border in spine of scapula. Insertion of m. Deltoid is in deltoid tuberosity of humerus. Action of m. Deltoid is abduction of shoulder joint, made mainly by medium fibers with stabilization by anterior and posterior fibers. Anterior fibers make flexion and, in dorsal decubitus, rotating medially shoulder joint; posterior fibers make extension and, in ventral decubitus, rotate laterally (127). Anterior head acts in flexion, medial acts in rotation and abduction of arm; medial part performs abduction in arm and posterior part the extension, lateral rotation (external) and abduction of the arm (95); this muscle is abduction of arm or shoulder flexion, in medial part the abduction of arm and in posterior part the abduction of arm and extension of shoulder (126) this muscle acts on superior fibers the flexion and medial rotation of the humerus, m. Middle Deltoid performs abduction of humerus at shoulder joint (after movement is performed by m. Supraspinatus), the posterior performs lateral extension and rotation of humerus. M. Deltoid also helps in arm lift (107). M. Deltoid has 7 portions (I and II: in anterior or clavicular fascicle; III: in middle or acromial fascicle; IV, V, VI and VII: posterior or spinal fascicle), considering portions in relation to their inverse action in abductor degrees (106).

1 APPENDIX E - DATA PROCESSING IN SOFTWARE MATLAB

```
function frechadaplus
% this mfile calculates EMG parameters for bow and arrow task.
% luis mochizuki Jul2014
[filename, pathname] = uigetfile('*.txt', 'Select the files','MultiSelect', 'on');
disp(' '),disp(' Openning files...')
nfile=length(filename);
mkdir(pathname,'data'); pathname3=[char(pathname),'data\'];
mkdir(pathname,'pic'); pathname2=[char(pathname),'pic\'];
mkdir(pathname,'feitos'); pathname1=[char(pathname),'feitos\'];
mkdir(pathname,'janela'); pathname4=[char(pathname),'janela\'];

for i=1:nfile
   file1=[char(pathname),char(filename(i))];
   fileA=char(filename(i));
   dados=load(file1);

   if findstr(fileA,'f1')
      flecha=1;
   elseif findstr(fileA,'f2')
      flecha=2;
   elseif findstr(fileA,'f3')
      flecha=3;
   elseif findstr(fileA,'f4')
      flecha=4;
   elseif findstr(fileA,'f5')
      flecha=5;
   elseif findstr(fileA,'f6')
      flecha=6;
   elseif findstr(fileA,'f7')
      flecha=7;
   end

   if findstr(fileA,'.')
      file=lower(fileA(1: findstr(fileA,'.')-1));
      files=lower(file);
      nome=lower(fileA(1:3));
   end

   if findstr(files,'aneb')
      sujeito=1;
   elseif findstr(files,'belab')
      sujeito=2;
   elseif findstr(files,'clarab')
      sujeito=3;
   elseif findstr(files,'danb')
      sujeito=4;
   elseif findstr(files,'larissab')
      sujeito=5;
   elseif findstr(files,'marcob')
      sujeito=6;
   elseif findstr(files,'marib')
      sujeito=7;
```

```
elseif findstr(files,'mbob')
    sujeito=8;
elseif findstr(files,'pedb')
    sujeito=9;
elseif findstr(files,'sarb')
    sujeito=10;
elseif findstr(files,'andreb')
    sujeito=11;
end

if findstr(files,'b1f')
    bloco=1;
elseif findstr(files,'b2f')
    bloco=2;
elseif findstr(files,'b3f')
    bloco=3;
elseif findstr(files,'b4f')
    bloco=4;
elseif findstr(files,'b5f')
    bloco=5;
elseif findstr(files,'b6f')
    bloco=6;
elseif findstr(files,'b7f')
    bloco=7;
elseif findstr(files,'b8f')
    bloco=8;
elseif findstr(files,'b9f')
    bloco=9;
elseif findstr(files,'b10f')
    bloco=10;
elseif findstr(files,'b11f')
    bloco=11;
elseif findstr(files,'b12f')
    bloco=12;
end

[b2,a2]=butter(4,20/1000);
dados(:,3:5)=filtfilt(b2,a2,dados(:,3:5));
[b2,a2]=butter(4,1/1000,'high');
dados(:,3:5)=filtfilt(b2,a2,dados(:,3:5));

emg=dados(:,6:17);
dados(:,2)=round(dados(:,2));
dados(2:end,2)=diff(dados(:,2));
dados(1,2)=0;
dados(dados(:,2)<0,2)=0;

[b,a]=butter(4,[59 61]/1000,'stop');    emg=filtfilt(b,a,emg);
[b,a]=butter(4,[119 121]/1000,'stop');    emg=filtfilt(b,a,emg);
[b,a]=butter(4,[179 181]/1000,'stop');    emg=filtfilt(b,a,emg);
[b,a]=butter(4,[239 241]/1000,'stop');    emg=filtfilt(b,a,emg);
[b,a]=butter(4,[299 301]/1000,'stop');    emg=filtfilt(b,a,emg);
[b,a]=butter(4,[359 361]/1000,'stop');    emg=filtfilt(b,a,emg);
[b,a]=butter(4,[419 421]/1000,'stop');    emg=filtfilt(b,a,emg);
[b,a]=butter(4,[479 481]/1000,'stop');    emg=filtfilt(b,a,emg);
[b,a]=butter(4,[539 541]/1000,'stop');    emg=filtfilt(b,a,emg);
```

```
[b,a]=butter(4,[599 601]/1000,'stop');    emg=filtfilt(b,a,emg);
[b,a]=butter(4,[659 661]/1000,'stop');    emg=filtfilt(b,a,emg);
[b,a]=butter(4,[719 721]/1000,'stop');    emg=filtfilt(b,a,emg);
[b,a]=butter(4,[779 781]/1000,'stop');    emg=filtfilt(b,a,emg);
[b,a]=butter(4,[839 841]/1000,'stop');    emg=filtfilt(b,a,emg);
[b,a]=butter(4,[899 901]/1000,'stop');    emg=filtfilt(b,a,emg);
[b,a]=butter(4,[959 961]/1000,'stop');    emg=filtfilt(b,a,emg);
[b,a]=butter(6,500/1000);    emg1=filtfilt(b,a,emg);
[b,a]=butter(6,20/1000);     emg2=filtfilt(b,a,emg1);
emg2=abs(detrend(emg2,'constant'));
emg2=tsmovavg(emg2,'s',80,1);
emg2=emg2(100:end-100,:);
emg1=emg1(100:end-100,:);
data=dados(100:end-100,2:end);

clf
data(:,5:16)=emg2;
dados1(dados(:,3:5)>=0.5,1:3)=1;
dados1(dados(:,3:5)<0.5,1:3)=0;
dados2=sum(dados1,2);
Xj=find(diff(dados2),1);

if Xj>999
   if Xj<length(dados2)-600
      Xi=Xj;
      Trigger=find(dados(:,2)>0);
   else
      plot(dados(:,2:5))
      [Xi,Yi]=ginput(1);
      Xi=round(Xi);
      Trigger=find(dados(:,2)>0);
   end
else
   plot(dados(:,2:5))
   [Xi,Yi]=ginput(1);
   Xi=round(Xi);
   Trigger=find(dados(:,2)>0);
end

data2=data(Xi-1000:Xi+600,:);
apa1=data2(901:1101,:);%apa1 = janela 50ms antes até 50 ms depois
apa2=data2(701:901,:);%apa2 = janela 150ms antes até 50 ms antes
apa3=data2(501:701,:);%apa3 = janela 250ms antes até 150 ms antes
apa4=data2(301:501,:);%apa4 = janela 350ms antes até 250 ms antes
apa5=data2(1:201,:);%apa5 = janela 500ms antes até 400 ms antes
apc1=data2(1101:1321,:);%apc1 = janela 50ms depois até 150 ms depois
apc2=data2(1321:1561,:);%apc2 = janela 150ms depois até 250 ms depois
apc3=data2(1361:1561,:);%apc3 = janela 250ms depois até 350 ms depois
m1=data2(1081:1121,:);%m1 = janela 40ms depois até 60 ms depois
m2=data2(1121:1161,:);%m2 = janela 60ms depois até 80 ms depois
m3=data2(1161:1361,:);%m3 = janela 80ms depois até 180 ms depois
mov=data2(301:1561,:);%mov = janela 350ms antes até 350 ms depois

%operaçoes nos dados
% correlacao cruzada
dados1=mov(:,5:16);
```

```
    [CC lags]=xcorr(dados1,1000,'coeff');

    [MaxCC,indices]=max(CC,[],1); %lag=0 representa coativacao e no maior valor de r o lag representa a latencia
    latencia=(indices-999).*0.5;
    % Cocontracao=CC(1001,1:16);

    %parametros do EMG
    %intensidade
    dataA(1,1:12)=rms(emg2(Xi+500:Xi+500,:),1);
    for j=1:12
       [NA(:,j),XA(:,j)] = hist(abs(emg2(:,j)));%histograma em 10 faixas
    end
    dataA(1,13:24)=XA(10,1:12);%95% do maximo EMG
    dataA(1,25:36)=rms(apa1(:,5:16),1);%RMS apa1
    dataA(1,37:48)=rms(apa2(:,5:16),1);%RMS apa2
    dataA(1,49:60)=rms(apa3(:,5:16),1);%RMS apa3
    dataA(1,61:72)=rms(apa4(:,5:16),1);%RMS apa4
    dataA(1,73:84)=rms(apa5(:,5:16),1);%RMS apa5
    dataA(1,85:96)=rms(apc1(:,5:16),1);%RMS apc1
    dataA(1,97:108)=rms(apc2(:,5:16),1);%RMS apc2
    dataA(1,109:120)=rms(apc3(:,5:16),1);%RMS apc3
    dataA(1,121:132)=rms(m1(:,5:16),1);%RMS m1
    dataA(1,133:144)=rms(m2(:,5:16),1);%RMS m2
    dataA(1,145:156)=rms(m3(:,5:16),1);%RMS m3
    dataA(1,157:168)=rms(mov(:,5:16),1);%RMS mov

    dadosSujeito=[bloco flecha sujeito];

    Tudo=[latencia dataA dadosSujeito];
    Trigger(end+1)=Xi;
    Trigger=Trigger';

    file_b=[pathname3,char(files),'.inicio'];     save(file_b ,'Trigger','-ascii');
    file_b=[pathname4,char(files),'.emg2'];    save(file_b ,'emg2','-ascii');
    file_b=[pathname4,char(files),'.emg1'];    save(file_b ,'emg1','-ascii');
    file_b=[pathname4,char(files),'.apa1'];    save(file_b ,'apa1','-ascii');
    file_b=[pathname4,char(files),'.apa2'];    save(file_b ,'apa2','-ascii');
    file_b=[pathname4,char(files),'.apa3'];    save(file_b ,'apa3','-ascii');
    file_b=[pathname4,char(files),'.apa4'];    save(file_b ,'apa4','-ascii');
    file_b=[pathname4,char(files),'.apa5'];    save(file_b ,'apa5','-ascii');
    file_b=[pathname4,char(files),'.apc1'];    save(file_b ,'apc1','-ascii');
    file_b=[pathname4,char(files),'.apc2'];    save(file_b ,'apc2','-ascii');
    file_b=[pathname4,char(files),'.apc3'];    save(file_b ,'apc3','-ascii');
    file_b=[pathname4,char(files),'.m1'];
    disp(['Salvando ' char(file_b) '  !!'])
    save(file_b ,'m1','-ascii');
    file_b=[pathname4,char(files),'.m2'];    save(file_b ,'m2','-ascii');
    file_b=[pathname4,char(files),'.m3'];    save(file_b ,'m3','-ascii');
    file_b=[pathname4,char(files),'.mov'];    save(file_b ,'mov','-ascii');
    file_b=[pathname3,char(files),'.var'];
    disp(['Salvando ' char(file_b) '  !!'])
    save(file_b ,'Tudo','-ascii');
       clear ace emg* dados* dataA ap* m*
       copyfile(char(file1),char(pathname1));
    delete(char(file1));
end
```