In the name of GOD

AGE AND GENDER RELATED CHANGES IN THE ELECTROMYOGRAM AND CARDIOVASCULAR SYSTEM DURING MUSCLE FATIGUE IN HUMANS

A Thesis Submitted for the Degree of Doctor of Philosophy in the Faculty of Medicine

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Summary

Muscle fatigue can be defined as a failure to maintain the required or expected force. This is a complex process, which is still not fully understood. Three sites are commonly thought of as the major locations of fatigue: the CNS, transmission at neuromuscular junction and individual fibres.

Muscle size and related neuromuscular function change dramatically across the human lifespan, initially showing rapid increases due to growth and then, later, more gradual decreases due to ageing. The physiological changes underlying the loss of muscle strength are not fully understood. Progressive muscular weakness is associated with a shrinking of muscle mass and muscle cross-section. This has been partially confirmed in the past, although, surprisingly, there has been little research on differences in fatigability between young and elderly subjects.

The purpose of this study was threefold, firstly, to determine if there is a relationship between fatigue and sex. Secondly, if there is a significant association between fatigue and age. Thirdly, to determine if these relationships are dependent on the cardiovascular system.

108 volunteers participated in this study. There were 53 females and 55 males. The ages of the volunteers ranged from 5 to 65 years. A series of experiments were performed to investigate the fatigue process during grip contractions at 60% of maximum voluntary effort. To facilitate this, the volunteers were divided into 6 age groups. Blood pressure and heart rate were measured before and

immediately after the contraction. The dominant or preferred forearm of the volunteer was always chosen for the experiments. Measuring the change in EMG signal during sustained and intermittent contractions assessed the state of fatigue.

The mean endurance time of females was significantly longer than that of males. In both females and males there were substantial reductions in median frequency of the EMG spectrum and longer half relaxation times. This indicates a strong fatigue state. The reduction in median frequency and increase in half relaxation time were similar in both females and males.

After both sustained and intermittent contractions there was no significant difference between males and females in systolic, diastolic blood pressure and heart rate.

It was found that lowest maximum voluntary grip was in the age group 1 (5-9 years) and the highest maximum voluntary grip was seen in group 3 (20-29 years). There were significant differences between mean maximum voluntary grip in groups 1 & 2 compared to groups 3, 4, 5 and 6.

There was a clear trend for longer endurance times in older groups. However, there were no significant differences in endurance time between the age groups. During sustained and intermittent contractions, the mean median frequency of the age group volunteers was not significantly different in the initial 5 seconds period. Neither were the median frequencies different in age groups at the end of the contraction.

There was no significant difference between the mean half relaxation time in different age groups at the beginning or at the end of the series of intermittent contractions.

The mean systolic and diastolic blood pressure before contractions and after both sustained and intermittent contractions show a progressive increase with age. These changes are what might be expected.

It was found that the mean heart rate after sustained contraction in children was significantly faster than adults. There were no significant differences between the mean heart rate in other groups.

Abbreviations

A	Ampere
AC	Alternative Current
Ach	Acetylcholine
ADP	Adenosine Diphosphate
AP	Action Potential
ATP	Adenosine Triphosphate
AVR	Average Rectified Value
BP	Blood pressure
BPM	Beats Per Minute
CAR	Central Activation Ratio
CED	Cambridge Electronic Design
CNS	Central Nervous System
CrP	Creatine phosphate
CSA	Cross Sectional Area
CV	Conduction Velocity
DC	Direct Current
E-C	Excitation-Contraction
EMG	Electromyography
FMF	Final Median Frequency
FFT	Fast Fourier Transform
IMF	Initial Median Frequency
HR	Heart Rate
Hz	Hertz
M	Mega
MAP	Mean Arterial Pressure

MDF	Median Frequency
ME	Myoelectric
MEP	Motor Evoked Potential
MFCV	Muscle Fibre Conduction Velocity
MNF	Mean Frequency
MPD	Myophosphorylase Deficiency
MSNA	Muscle Sympathetic Nerve Activity
MU	Motor Unit
MUAP	Motor Unit Action Potential
MUAPT	Motor Unit Action Potential Train
mV	Millivolt
MVC	Maximum Voluntary Contraction
MVE	Maximum Voluntary Contraction
N L	Neuro Log
NME	Neuromuscular Efficiency
NMR	Nuclear Magnetic Resonance
pA	Pico Ampere
PC	Personal Computer
PCr	Phosphocreatine
RMS	Root Mean Square
Sec	Second
SEMG	Surface Electromyography
SR	Sarcoplasmic Reticulum
T	Time

Chapter 1

Introduction and literature review

Skeletal muscle fatigue

The first problem encountered when discussing fatigue is that the word itself has a number of different meanings such as exhausted, tired, over-used, disinclined, etc (Jones and Round, 1999).

There are several different definitions of muscle fatigue. The most common definition is failure to maintain the required or expected force and is accompanied by changes in muscle electrical activity, or changes in perceived effort level for a given force level (Dimitrova and Dimitrov, 2002). Bigland-Ritchie and Woods (1984) demonstrated that physiological events leading to fatigue in submaximal activity begin soon after the onset of activity and there is a decrement in the maximum force producing capability of the muscle. This led them to define fatigue as a decline in the capacity of a muscle to generate force. It was mentioned by Basmajian and De Luca (1985) that fatigue is a time-dependent process and so does not occur at a particular point in time or during a specific time interval. This implies that changes take place within the muscle before an observable reduction in force output occurs.

Muscle fatigue is defined as any exercise-induced reduction in the maximal capacity to generate force or power output (Vollestad, 1997a). Fatigue has been also defined as "a failure to maintain the required or expected force" (Edwards, 1981). However, this latter definition does not acknowledge the fact that fatigue changes have already taken place before this failure occurs. A more comprehensive definition is "*any reduction in the force-generating capacity of the entire neuromuscular system, regardless of the force expected*"(Bigland-Ritchie and Woods, 1984). Vollestad, Serjersted, Bahr, Bigland-Ritchie and Woods (1988), make a distinction between fatigue and exhaustion, defining exhaustion as "*an inability to sustain contraction/exercise at the target force/intensity*".

Localised muscle fatigue is characterised by changes in physiological processes occurring in a muscle or a group of synergist muscle performing a contraction. Muscle soreness, stiffness and pain are symptoms frequently associated with fatigue (Muldover and Borg-Stein, 1994). Objective criteria to document and quantify fatigue are limited. Serum lactic acid levels have been used to measure fatigue, but one limitation of this method is that a blood sample must be obtained (Muldover and Borg-Stein, 1994). Spectral analysis of the electromyogram has been proposed as a noninvasive way to evaluate muscle fatigue.

Three sites have been evaluated as potential site of fatigue: these are the central nervous system (CNS), neuromuscular junction, and individual muscle fibres (Bigland-Ritchie and Woods, 1984; Vollestad, 1997a). There is continuing debate about the ultimate cause of fatigue in many activities (Bellemare and Garzanit, 1988; Fuglevand, Zachowski, Huey and Enoka, 1993). The type, intensity and duration of the muscle contraction affects the cause of muscular fatigue (Bigland-Ritchie and Woods, 1984).

A combination of central and peripheral factors may be involved during isotonic and isokinetic contractions (Muldover and Borg-Stein, 1994). However, during a sustained submaximal contraction, the rate of firing of motor units tends to decline progressively (Bigland-Ritchie and Woods, 1984). In this case, the force can be maintained by recruitment of fresh motor units (Lippold, Redfern and Vuco, 1960). The mean motor neurone discharge rates decline with sustained submaximal voluntary contractions (Bigland-Ritchie, Cafarelli and Vollestad, 1986a; Sacco, Newberry and McFadden, 1997).

The mechanism of fatigue is complex and dependent on a variety of factors. Muscle fatigue is accompanied by reduced force generating capacity, slowing of muscle conduction velocity and contractile speed and the accumulation of metabolites (Henneman and Olson, 1965; Bigland-Ritchie and Woods, 1984; Merletti, Knaflitz and De Luca, 1992a).

Physiology of skeletal muscle

Any description of skeletal muscle must include structure and function because they are so closely linked (Lieber, 1992). Skeletal muscle does not work in isolation. It requires an intact pathway from the central nervous system to perform its function normally *in vivo*. This includes the brain, spinal cord, peripheral nerve and neuromuscular junction.

Voluntary muscle contraction requires a large number of controlled sequential activities usually starting in the premotor area of the frontal cortex (Huxley, 1957). From here, a signal is transmitted through the internal capsule to the brainstem while corollary signals reach the cerebellum, basal ganglia, and thalamus, allowing for refinement and co-ordination of movement. In the spinal cord, through the corticospinal tract, anterior horn cells are activated along with the other components of its motor unit (motor axon, nerve terminals, neuromuscular junctions, and muscle fibres). Control of agonist-antagonist muscle pairs is exerted through reciprocal inhibition at the spinal cord segmental level.

Neural activity precedes normal muscular contraction; hence, the signal must be sent from the central nervous system to the peripheral nerve in the muscle. The interface between the nerve and muscle is the neuromuscular junction, which includes a repository for acetylcholine at the nerve ending. Acetylcholine can diffuse across a small indentation on the muscle fibre surface, known as the synaptic cleft, to bind to its receptor on the muscle membrane or sarcolemma. Acetylcholine binding produce activated membrane conduction channels and initiates an action potential that travels along the sarcolemma. The transverse tubules, invaginations along the sarcolemma, transmit the action potential deep into the muscle fibre, which signals the sarcoplasmic reticulum (SR) to release calcium (Peachey, 1965). The calcium binds to troponin, a regulatory protein attached to actin filament, causing a conformational change that allows actin and myosin to bind. The actin-myosin cross-bridge provides the mechanical force generation, resulting in sliding of the myofilaments. Throughout the cycling of the myofilaments, calcium is pumped back into the SR, aided by SR Ca^{2+} adenosinetriphosphatase. After the action potential stops, relaxation requires complete calcium re-uptake.

Energy for the muscle contraction and relaxation is derived from adenosine triphosphate. ATP stored locally can sustain maximal muscle contraction for only a few seconds. Adenosine diphosphate

(ADP) must be phosphorylated using phosphocreatine (PCr) as the substrate to resynthesize ATP for ongoing activity (Cain and Davies, 1962). The combined store of ATP and PCr in muscle is adequate to maintain maximal contraction for only an additional 10 to 20 seconds (Cooke and Pate, 1985). The body has three other fuels whose metabolism provides energy for the synthesis of ATP, glucose, fat, and protein. Muscle glycogen is a main energy source during short duration exercise. The body can store even larger amounts of triglycerides that must be broken down to fatty acids in order to be used. During prolonged exercise (for example, road cycling or ultramarathoning), free fatty acids are a more significant energy source.

Adult muscle fibres vary considerably in size and length between various muscles in the body and between individuals of different sex, build and age. In a normal adult the mean cross-sectional fibre areas are between 2500μm^2 (small woman) and 7500μm^2 (large man), representing a variation in diameter of about 50 to 100 μm^2. Fibres from a muscle such as the quadriceps are on average larger, in any individuals, than fibres from smaller muscles such as the masseter or muscles of the hand. Fibre length varies greatly, from a few millimetres in the ciliary muscle of the eye to 10 cm or more in the sartorius, a long, strap-like muscle in the inner thigh (Squire, Luther and Trinick, 1987; Jones and Round, 1999).

Skeletal muscle fibre classification historically has been based on morphologic, contractile and metabolic properties (Dugan and Frontera, 2000). Fibre typing based on energy pathways used is one method commonly employed. They may also be classified into functional categories of slow or fast twitch, fatigue resistant or fatigue susceptible (Denny-Brown, 1929; Burke, 1967; Salmons and Sreter, 1976). Barany's work in the 1960s linked the biochemical and physiological properties by associating myosin ATPase activity with contraction speed (Barany, 1967). A histochemical assay for myosin ATPase activity is used to distinguish between slow and fast fibres. The most commonly used fibre type identification involves three groups: slow oxidative fibres (type I); fast oxidative glycolytic fibres (type IIA); and fast glycolytic fibres (type IIB). Resistance to fatigue is highest in type 1 and lowest in type IIB fibres. Type I fatigue-resistant muscle fibre tend to be recruited initially as voluntary muscle activation increases (Nielsen, 1983; Wright, McCloskey and Fitzpatrick, 1999).

Central and peripheral fatigue

Human muscle fatigue may develop for a variety of reasons.

Different mechanisms may be responsible for the fatigue under different conditions (Dugan and Frontera, 2000).

Physiologically, local muscle fatigue, defined as a loss of force producing capacity as a result of exercise (Gandevia, 1998) can both originate from peripheral and central factors.

Peripheral fatigue results from variations in the muscle itself, like changes in the neuromuscular junction and sarcolemmal membrane, accumulation of metabolite and depletion of fuels (Kirkendall, 1990). Central fatigue can be located in both the central and peripheral nervous system. If central fatigue occurs, muscle force decreases because of decrease of neural drive (Gandevia, 1998; Kent-Braun, 1999). Failure of force production may occur at the various sites along the pathway from the central nervous system through to the intramuscular, contractile machinery. The contribution of impaired central motor drive to muscle fatigue has been investigated, with some researchers finding little or no central failure (Merton, 1954; Bigland-Ritchie, Dawson and Johansson, 1986b), and others reporting significant central activation failure during fatiguing exercise (Bigland-Ritchie, Jones, Hosking and Edwards, 1978).

Peripheral factors in fatigue primarily include metabolic inhibition of the contractile process and excitation-contraction coupling failure (Cady, Jones, Lynn and Newham, 1989b; Bakels and Kernell, 1993; De Groote, Massie, Boska, Gober, Miller and Weiner, 1993). Prolonged low-intensity exercise has been associated with failure of excitation-contraction coupling (Baker et al., 1993; Moussavi, Carson, Boska, Weiner and Miller, 1989), which has a very slow recovery time (Edwards, Hill, Jones and Merton, 1977). Accumulation of intramuscular metabolites has been implicated in the development of fatigue during high-intensity exercise, although agreement on which metabolite plays the most important role is still lacking (Cady et al., 1989b; Baker, Kostov, Miller and Weiner, 1993). Reduced excitability of neuromuscular transmission has been reported to occur under some fatiguing conditions (Stephens and Taylor, 1972; Fuglevand et al., 1993), however this does not appear to be a common occurrence, particularly during voluntary contractions. The manifestation of central fatigue, defined as a progressive exercise-induced reduction in the level of voluntary activation of a muscle, appears to be task-dependent, and may be mediated by intrinsic motoneuronal, spinal, and supraspinal factors (Gandevia, 2001). The level of voluntary drive during an effort (voluntary activation) has been examined using twitch interpolation, in which one or more electrical stimuli (single, double, or tetanic pulses) are delivered to the motor axons innervating the muscle (Gandevia, 2001). More recently, transcranial magnetic stimulation of the motor cortex has been used to interpolate MVCs under non-fatigued conditions and during fatigue paradigms to examine the supraspinal component of voluntary activation (Gandevia, 2001). Complementary to this twitch interpolation technique, transcranial magnetic stimulation generates a motor evoked potential (MEP) followed by an electromyographic (EMG) silent period when applied during the voluntary contraction (Taylor and Gandevia, 2001).

Impaired firing rate modulation or reduced motor unit recruitment during fatiguing exercise is often referred to as central fatigue. Any breakdown in muscular activation that is proximal to the point of stimulation of motor nerve is generally considered central. Impaired central activation of muscle during exercise is measured in two different ways. During a maximal voluntary contraction, superimposed electrical stimulation of the motor nerve, which may produce added force from incompletely activated muscle fibres, provides a quantitative measure of central activation failure. When the muscle is fully activated, the superimposed electrical stimulus produces no added force (Lloyd, Gandevia and Hales, 1991). Previous workers have variously utilised the superimposed twitch, paired stimuli, and brief trains of tetanic stimuli (Gandevia and McKenzie, 1985; Kent-Braun, Sharma and Weiner, 1993a; Sharma, Kent-Braun, Mynhier, Weiner and Miller, 1994). The sites at which fatigue may occur are the central nervous system (CNS), the motor end-plate, the cell membrane, the transverse tubular system and in the energy supply to the muscle. On the other hand, following short-duration exercise, the time course of recovery of inorganic phosphate and muscular force are almost identical suggesting that the recovery of force depended primarily upon the recovery of metabolites after short-duration exercise. By contrast, the recovery of force was delayed following long duration exercise compared with the recovery of inorganic phosphate and other metabolites. The absence of change in the compound muscle action potential suggests that the neuromuscular junction and muscle membrane did not contribute significantly to the muscle fatigue (Baker et al., 1993; Miller, Kent-Braun, Sharma and Weiner, 1995).

Thus, although various sites along the pathway of force production have been implicated in human skeletal muscle fatigue, the relative roles of central and peripheral factors in the development of muscle fatigue remain unclear (Kent-Braun, 1999).

High and low frequency fatigue

High and low frequency stimulation patterns appear to result in different fatigue mechanisms. High frequency stimulation is associated with a decrease in the energy of total EMG power spectrum. This would seem to suggest that high frequency stimulation is not good for long term activation and so the body reduces the frequency of stimulation.

Each AP leads to Na^+/K^+ movement. A large number of APs will produce an increase in $[K^+]$ in the tubules leading to chronic depolarisation of the T-system (e.g. from –90 mV to ~-60 mV), which prevents the voltage-dependent sodium channels in the T-system from resetting (i.e. they stay 'inactivated'). In the extreme, this would mean APs would not propagate into and along the T-system, and hence there would be no activation of the voltage-sensor (VS) coupling to the Ca^{2+} release channel, and hence no muscle contraction. This is called high frequency fatigue. It is induced rapidly (ie. over seconds) by high frequency stimulation in rat (eg. 100 – 200Hz), but recovery is also very rapid (over seconds) upon cessation of stimulation due to K^+ both diffusing out of the T-system and being pumped back into the cell by the Na-K-ATPase in the T-system membrane (Ruff, Simiocini and Stuhmer, 1987). They have identified a slow inactivation of the inward Na^+ current, which occurs when the membrane is mildly depolarised, and have suggested that this may underlie the loss of activation seen during high frequency fatigue. Ruff and Whittlesey (1992) made similar observations on human muscle and have shown that fast fibres have a greater susceptibility to this type of inactivation. This type of fatigue is not caused by metabolic changes within the fibre.

Long–duration fatigue (also known as 'low-frequency fatigue') is due to a reduction in Ca^{2+} released (Jones, 1996). This can also lead to structural changes or damage resulting in very prolonged fatigue.

Thus low frequency fatigue is selective loss of force at low stimulation frequencies, and is thought to be a result of impaired excitation-contraction coupling. It is generally long lasting, and is also more pronounced following eccentric contractions i.e. those made when the muscle is stretched during a contraction (Newman, Mills, Quiglley and Edwards, 1983). The activities of everyday life are mostly the result of submaximal contractions induced by low frequency stimulation i.e. 10 to 30 Hz (Grimby and Hannerz, 1977). Low frequency fatigue is more evident in eccentrically contracted muscle (Gibson and Edwards, 1985). Frequencies in excess of 50Hz are rarely seen with voluntary activation of human muscle, and for this reason there has been some doubt as to whether high-frequency fatigue is a significant feature of normal activity (Jones, 1996).

High frequency fatigue is the selective loss of force at high stimulation frequencies, and is considered to be due to impaired transmission at the neuromuscular junction (Stephens and Taylor, 1972) and/or impaired propagation of muscle action potential (Jones, Bigland-Ritchie and Edwards, 1979). High frequency fatigue can occur as a result of cooling of muscle and of experimentally produced ischaemic fatigue (Edwards, 1984). The effect of high frequency fatigue is that it reduces the maximum force output of the muscle, whether by voluntary effort or by electrical stimulation.

Recovery from fatigue depends on the mode of fatigue. Recovery from high frequency fatigue seems to occur rapidly, whereas low frequency fatigue seems to take several hours.

Excitation-contraction coupling impairment

The other likely source of activation impairment, besides central fatigue, is excitation-contraction coupling. Probably the most reliable measure of impaired excitation contraction coupling is the existence of long duration fatigue following the completion of muscular exercise. Long duration fatigue has also been called low-frequency fatigue. The phenomenon was first attributed to excitation-contraction-coupling impairment by Edwards and colleagues (1977). In a subsequent study Bigland-Ritchie and colleagues observed a form of fatigue that was associated with very little alteration in metabolites as analysed by muscle biopsy (Bigland-Ritchie et al., 1986b). In 1989 Moussavi et al. observed that low intensity intermittent exercise could produce not only fatigue associated with very metabolic alteration as examined by (Nuclear Magnetic Resonance) NMR spectroscopy, but also with some long lasting impairment of muscular force generation. Again, this pattern was attributed to excitation-contraction-coupling impairment.

Half relaxation time

Muscle fatigue is often associated with slowing of contractile speed (Fitts, 1994). Repetitive isometric contractions induce a progressive increase in the energy cost of contraction, demonstrated by an increased oxygen uptake in the muscle (Sahlin, Cizinsky, Warholm and Hoberg, 1992), and a higher rate of metabolic heat production during contraction (Saugen and Vollestad, 1996). Contractile speed is closely associated with the metabolic heat production and energy cost of contraction (Wiles and Edwards, 1982; Fitts, 1994), suggesting that the rate of force and relaxation may increase with fatigue from repetitive isometric exercise. Thus the exercise-induced changes in muscle energetic and activation pattern occur in a direction opposite to that seen during sustained voluntary or electrically stimulated contractions (Edwards, Hill and Jones, 1975a; Bigland-Ritchie, Thomas, Rice, Howarth and Woods, 1992).

A slowing of relaxation is one of three predominant changes seen in localised muscle fatigue, the other two being the response to high frequency stimulation (high frequency fatigue) and changes in twitch amplitude and shape (Jones, 1981). The rate of relaxation from an isometric contraction has been known to decrease with fatigue. Prolonged submaximal exercise is associated with a fatigue-induced recruitment of the faster type II muscle fibres, which have a higher energy cost of contraction compared with type I (Burke, 1981) . To what extent this increased activation of type II fibres causes a temporal rise in energy turnover can be examined by comparing the responses during repetitive isometric exercise at different target force levels. With an increased target force, a larger proportion of type II fibres will be activated from the start and the rise in energy cost of contraction and, consequently, contractile speed is expected to be smaller.

The half relaxation time of the latter part of the time course of relaxation, the exponential phase, may increase by a factor of two or three. In addition, there is no recovery of the relaxation rate under anaerobic conditions (Edwards, Hill and Jones, 1972). The reasons for these phenomena are still not completely understood.

There are two main possibilities explaining the time course of relaxation:

-The reduced rate of re-accumulation of calcium by sarcoplasmic reticulum (Cady, Elshove, Jones and Moll, 1989).

-The reduce rate of dissociation of cross-bridges after the activating calcium has been removed (Edwards et al., 1975 a).

The dissociation of myosin cross-bridges is required for relaxation from an isometric contraction, and this dissociation requires the binding of ATP to the myosin molecule. It has been shown that the slower the relaxation, the slower the ATP turnover (Edwards et al., 1975 a). However, Edwards et al. (1975a) point out that it seems unlikely that a reduced amount of ATP as a substrate for actomyosin ATPase is the cause of slower relaxation, but rather than it has caused a change in regulatory subunits. Alternatively, this reduced concentration of ATP may possibly result in a reduced rate of calcium pumping by sarcoplasmic reticulum (Dawson, Gadian and Wilkie, 1980). There has been evidence to support the contention that slowing of relaxation is associated with reduced calcium uptake by sarcoplasmic reticulum (Gollnick, Korge, Krpakka and Saltin, 1991). Experiments were conducted on the quadriceps femoris muscle, and repeated muscle biopsies were taken. It was found that the half relaxation time was measured on exhaustion, with full recovery after 30 minutes. At exhaustion the calcium uptake by the sarcoplasmic reticulum was reduced to 58% of the pre-exercise value. Gollnick et al. (1991) suggest that some change to the sarcoplasmic reticulum occurs on exercise that depresses the Ca^+ activated ATPase and reduces Ca^+ uptake.

The concept of a reduced turnover of cross-bridges is supported by studies involving muscle heat production, where heat production falls as relaxation slows. It has been calculated that the reduced heat production might correspond to an approximately three-fold reduction in ATP turnover. These calculations are based on the heat produced from the splitting of phosphoryl creatine and from glycolysis (Edwards et al., 1975 a). With a reduction in relaxation rate there is a reduction in ATP and creatine phosphate, and in addition there is an accumulation of lactic acid and H^+. It has been shown in patients with myophosphorylase deficiency (MPD) that there is a slowing of relaxation with fatigue, even though these patients do not produce lactic acid, and so accumulation of lactic acid is unlikely to be a cause.

It was previously demonstrated that only moderate initial changes in high-energy P_i, lactate and H^+ levels occur during repetitive isometric exercise at 30% MVC (Vollestad et al., 1988; Sahlin et al., 1992). Furthermore, Vollestad et al. (1990) and Sahlin et al. (1992) estimated that the rate of ATP turnover during this type of exercise is well below the limits for aerobic metabolism. The low amounts of lactate production support the opinion that the ATP demand during this type of exercise is adequately met by oxidative ATP resynthesis. The absence of large changes in substrate and metabolite levels may explain why contractile slowing was not found during repetitive isometric exercise at the two lowest force levels. Even though Vollestad et al. (1997) had no direct evidence of changes in metabolites in their study, it is reasonable to assume that the 60% MVC repetitive isometric exercise may have induced larger changes in high-energy P_i and other metabolites compared with the 30 and 45% MVC exercise. These chemical changes may have caused the slowing of relaxation demonstrated for the tetanic contractions during the 60% MVC exercise. The slowing of relaxation was reversed with a time course similar to recovery of metabolite changes after exercise (Saugen, Vollestad, Gibson, Martin and Edwards, 1997). However, no known metabolic factors can explain why half relaxation time values decreased during the low-force contractions or in the recovery period.

History of electromyography

The earliest investigations of surface EMG can be traced back to the mid 1600s. Francesco Redi, who worked with the electric ray fish documented that a highly specialized muscle tissue was the source of its energy. Basmajian & De Luca (1985) presented an account of the history of electromyography, where they state that the relationship between muscle contraction and electricity was first observed by Galvani in 1791. They also pointed out that the first detection of signals elicited voluntarily from muscle was reported in 1849 by Du Bois-Reymound. Methods of measuring electrical signals from human muscles were greatly simplified by the introduction of the metal surface electrode in 1907 by Piper. A significant advance for clinical electromyography was made by the introduction of the needle electrode in 1929 by Adrian and Bronk. Due to continuing improvements in EMG instrumentation during the 1930's, 40's and 50's, surface electromyography began to be used more widely for the study of normal and abnormal muscle function. During the thirties, Edmund Jacobson, the father of progressive relaxation, used sEMG extensively to study the effects of imagination and emotion on a variety of muscles (Jacobson, 1976). The development of silver/silver chloride and fine-wire electrodes in the late 1950's caused an increase in the use of EMG for kinesiological studies.

During the 1960's, biofeedback was born. Part of the impetus for this birth was the work on single motor unit training by (Basmajian, 1963).

In the early 1980's, Cram and Steger introduced a clinical method for scanning a variety of muscles using a hand held surface EMG sensing device (Cram and Steger, 1983).

Composition of the surface electromyogram

The myoelectric signal (ME) is the electrical representation of the neuromuscular activity of a contracting muscle. The ME signal produced from a constant force isometric contraction depends on the firing rate of the motor units, the shape and the number of the motor-unit action-potentials (MUAPs), and number of synchronised MUAP trains (MUPATs). These are all characteristics derived from the spatial-temporal summation of MUAPTs (De Luca and Van Dyk, 1975).

The MUAPTs are a sequence of MUAPs. The MUAP is a summation of the action potentials from muscle fibres innervated by a single motor unit (Merletti et al., 1992a). Each active MUAP generates a current in the surrounding volume conductor. The polyphasic signal recorded as the surface electromyogram (EMG) signal is the net sum of these two motor units. (Merletti et al., 1992a; Kamen and Caldwell, 1996). The use of surface electrodes permits the evaluation of groups of motor units that are active near the electrode. Motor units of short duration contribute more high-frequency energy than units with a long duration (Lindstrom and Petersen, 1981). Therefore, the myoelectric signal is affected by the physiologic and anatomic properties of the muscles and the control mechanism of the peripheral nervous system (De Luca, 1979; Merletti et al., 1992a; Kamen and Caldwell, 1996).

Surface EMG and fatigue

Parameters that can be derived from the ME include the root –mean – square (RMS) value; the mean integrated rectified value, and both the mean frequencies (MNF) and median frequencies (MDF). Many studies have shown potential uses for these paramcters in evaluating fatigue. The conduction velocity and the central activation ratio (CAR) are other measurements often used to evaluate fatigue (Komi and Vhtasalo, 1976; Merletti and Lowe, 1997; Merletti, Roy, Kupa, Roatta and Granata, 1999).

The MNF is the average frequency. The MDF is the frequency at which the spectrum is divided into two regions with equal power

(Stulen and De Luca, 1981). Both have been used to measure fatigue, but each has its own limitations and advantages.

Changes to the power spectrum

Failure to maintain the required or expected force, defined as muscle fatigue, is accompanied by changes in muscle electrical activity. Piper (1912) was the first to observed a reduction in frequency of the surface EMG (Piper rhythm) when a contraction was sustained. Besides such a frequency shift, Cobb and Forbes (1923) found a consistent increase in the amplitude of surface recorded EMG. Since then, the studies can be divided into investigations directed at discovering signs of fatigue and/or causes for fatigue.

Opinions agree that muscle fibre propagation velocity (MFPV) decreases with fatigue and that EMG power spectrum shifts during fatigue, mainly owing to a slowdown of MFPV (Gerdle, Larsson and Karlsson, 2000; Hagg, Luttmann and Jager, 2000; Merletti, Farina, Gazzoni and Schieroni, 2002). The fact that spectral characteristics can drop even without any changes in MFPV (Linssen, Jacobs, Stegeman, Joosten and Moleman, 1990), or in proportion exceeding the MFPV changes (Krogh-Lund and Jorgensen, 1993b) has prompted many authors to conclude that there must be other factors contributing to the observed shift in the power spectrum . These factors and the way they could affect EMG spectral characteristics have been so far unknown.

Voluntary and electrically elicited EMG signals have a similar spectral shift during fatigue (Merletti and Lo Conte, 1995). Simulations performed by Lindström et al. (1977) have shown the power spectra of interference EMG signals and of motor unit potential (MUP) as essentially similar and dispersion in the action potentials produced by individual fibres within MU as leading to dramatic changes in the MUP power spectrum. Thus, an analysis of factors affecting the spectral characteristics of MUPs or M-waves can help us understand the reasons for EMG power spectrum shift.

Amplitude

The two parameters of amplitude commonly used to evaluate fatigue are the average rectified value (AVR) and the root mean square value (RMS). The AVR represents a mean voltage value. It is calculated by taking the area between the rectified signal and the time axis during time interval T and divided by T. The RMS is calculated by taking the square root of the mean power value that is calculated by dividing the energy of the signal during a time interval of duration T by the value of T (Merletti et al., 1992a). The normalised amplitude can be calculated from the RMS amplitude by dividing the RMS amplitude of each burst by the mean force generated in the burst. The reciprocal of this normalised EMG value is believed to represent neuromuscular efficiency (NME=1/normlised amplitude) (Linssen, Stegeman and Joosten, 1993).

The amplitude changes seem to be more complicated and contradictory since data on increased, almost unchanged, and decreased amplitude characteristics of the EMG, M-wave or MUP during fatigue can be found in the literature. Moreover, simultaneous decrease and increase in amplitude of MUP and M-wave, detected with indwelling and surface electrodes, were referred to as paradoxical. Analysis of changes in MUP or M-wave size and shape with fatigue suggests peripheral factors that contribute (together with the central factors) to changes in amplitude and spectral characteristics of EMG signals.

Frequency decrease and amplitude increase have a common origin, as the local accumulation of metabolites results in a decrease in conduction velocity and hence a longer time duration of motor unit waveforms (Basmajian and De Luca, 1985).

The RMS amplitude has a variable response during contractions that appears to be related to the force of the contraction. For sustained submaximal contractions, the RMS amplitude increases initially but begins to decrease with the impending mechanical fatigue (Bigland-Ritchie et al., 1986b; Merletti, Lo Conte and Orizio, 1991). Factors believed to be responsible for the initial increase of the SEMG amplitude during submaximal exercise include synchronisation between motor unit (MU) firing patterns, recruitment of additional MUs, and alterations in the firing frequency of individual motor units (De Luca and Van Dyk, 1975; Bigland-Ritchie et al., 1986b; Bigland-Ritchie, Furbush and Woods, 1986c). Linsesen et al. (1993) found an initial increase of the normalised SEMG amplitude during submaximal exercise followed by a slight decline. For sustained maximal contractions, a decrease in the amplitude of the myoelectric signal has been demonstrated (Bigland-Ritchie, Johanson and Lippold 1983a; Moritani, Murro and Nagata, 1986; Gerdle and Fugi-Meyer, 1992). Therefore, different motor unit recruitment and rate-coding mechanisms for these different levels of voluntary contractions may exist (Bigland-Ritchie et al., 1983a; Moritani et al., 1986).

Mechanism of the spectral changes

During sustained fatiguing contractions, the EMG frequency spectrum is observed to shift towards the lower frequencies. These spectral changes are generally attributed to a progressive decrease in muscle fibre conduction velocity (MFCV), which also contributes to an increase in the amplitude of the surface EMG signal (Merletti and Lowe, 1997).

The primary mechanism accounting for myoelectric power spectral shift with constant-force isometric contraction has been debated in recent years.

Lindstrom et al. (1970) proposed that progressive slowing of muscle conduction velocity leads to an increase in duration of the individual MUAPs. The EMG shifts to lower frequencies because the broader duration MUAPs consist of lower frequency components (Eberstien and Beattie, 1985).

Borman et al. (1985) concluded that factors other than muscle fibre conduction velocity affect the myoelectric signal during high-level contraction. Their conclusion was based on their finding that spectral parameters decreased approximately twice as much as did the conduction velocity (Merletti, Knaflitz and De Luca, 1990; Yaar and Niles, 1992; Krogh-Lund and Jorgensen, 1993b). Other factors that may contribute to the spectral compression that occurs during fatigue include changes in synchronization between motor units and recruitment of new motor units (Borman, Bilotto and De Luca, 1985; Krogh-Lund and Jorgensen, 1993b). The benefit of the spectral shift toward lower frequencies is unclear. Bigland-Ritchie et al. (1983) suggested that it might be a safeguard to maintain force output without compromising neuromuscular junction transmission.

Conduction velocity

The muscle fibre conduction velocity (MFCV) ranges from 2m/s to 6m/s and is inversely related to the duration of the action potential (De Luca, 1979; Kamen and Caldwell, 1996). The conduction velocity of action potentials along the muscle fibres decreases with high-force-level contractions (Bigland-Ritchie et al., 1983a; Borman et al., 1985). An accumulation of lactic acid has been speculated to cause the slowed conduction velocity. The decrease of the MFCV is believed to play a prominent role in compressing the power density spectrum to lower frequencies during fatigue (Krogh-Lund, 1993a).

Technical issues

Multiple factors can affect the myoelectric signal; these include factors related to environment issues such as temperature and blood flow. The mechanism used to fatigue the muscle also can influence the signal. Factors related to instrumentation can modify the signal such as the frequency setting, electrode type and placement and data collection system.

Environmental factors

Temperature

Lower muscle temperatures have been reported to slow muscle fibre conduction velocity (CV) and lower the initial median power frequency (Holewijn and Heus, 1992; Kamen and Caldwell, 1996). Holewijn et al. 1992 showed that at a temperature of 15°C, the MNF started at a significantly lower value but then increased with contraction time. Typically an increase in MNF is not seen with fatigue, and this variation was attributed to an increase in muscle temperature due to the ongoing contraction (Merletti, Sabbahi and De Luca, 1984; Holewijn and Heus, 1992). Merletti et al. (1984) found a linear relationship between the initial median frequency of the myoelectric signal and the intramuscular temperature within the range of 15°C to 33°C. The initial MDF was shown to decrease as the muscle became colder.

Blood flow

Muscle blood flow has an important role in the development of muscle fatigue because it alters the depletion of energy substrates and the accumulation of metabolic by-products, which ultimately affects the contractile properties of the exercising muscle (Bigland-Ritchie, Rice, Garland and Walsh, 1995). Studies measuring spectral parameters of ischaemic muscle during a constant-force isometric contraction have shown that CV is reduced and that the initial median frequency is lower (Merletti et al., 1984). These alterations have been attributed to the accumulation of metabolic by-products (Merletti et al., 1984). Jones et al (1979) used a sphygmomanometer cuff to prevent the return of blood flow. During maximal contraction, blood flow is interrupted to the region. The cuff is used to maintain this environment when the experimental protocol leads to brief cessations in contraction that can cause return of blood flow. The cuff also prevents blood flow return when the force of the contraction is decreased to a point where circulation to the muscle is no longer occluded (Jones et al., 1979; Merletti et al., 1984).

Voluntary contraction versus maximal nerve stimulation

Two of the techniques used to fatigue muscle groups are voluntary contraction and electrical stimulation. During voluntary muscle contraction, the recruitment of motor units progresses from small to large units. It has been shown that the smaller motor units have slower conduction velocities. During electrically elicited contraction of the muscle, the order of recruitment of motor units with an increasing stimulus appears often to follow the same principle, though not as consistently as with voluntary contraction (Merletti et al., 1990; Merletti et al., 1992a).

Jones et al. (1979) compared the loss of force that occurred with MVC in humans to the loss of force that occurs with maximal nerve stimulation. A sustained MVC resulted in a slower loss of force than that which occurred during prolonged stimulation at 80 Hz. They also observed that stimulation of fatigued muscle at high frequency produces less force than with stimulation at low frequency. Therefore they concluded that it was advantageous to reduce the natural firing frequency during the course of sustained voluntary contraction (Jones et al., 1979). Merletti (1992a) believed that electrical stimulation might result in a more rapid rate of muscle fatigue than occurs with voluntary contraction. The difference in the observed rates of fatigue produced by voluntary contraction and electrical stimulation suggests that the results obtained by each may not be interchangeable.

Influences of muscle length on the EMG signal

Muscle fibre conduction velocity (MFCV) decreases with increasing muscle length. This finding may be a result of a decrease in muscle fibre diameter (Kamen and Caldwell, 1996). Mean frequency of SEMG has been shown to increase with decreased muscle length (Potvin, 1997). Therefore, interpretation of SEMG activity during dynamic contraction can be difficult; this is primarily due to change in muscle electrical activity with muscle length.

Soft tissue

Soft tissue acts as a low-pass filter and can modify the signal by reducing the higher frequencies in the spectral frequency distribution. This results in a relative predominance of the lower frequencies (Merletti et al., 1984). The filtering effect of soft tissue should be considered when designing studies (Linssen et al., 1993).

Instrumentation

Electrodes

The recording electrode is typically bipolar. Two parallel bars 1mm in diameter, 10 mm long, and 10 mm apart are commonly used in spectral analysis studies (Merletti and De Luca, 1989). The electrode affects the amplitude of the action potential by its filtering properties that are dependent on the size of the recording contacts, the distance between the electrodes, and chemical properties of the metal electrolyte interface (De Luca, 1979).

There are some instances when surface electrodes are inadequate and intramuscular electrodes are needed, such as when studying lip muscles (Kamen and Caldwell, 1996). Intramuscular electrodes, however, do not always produce recordings similar to those obtained with surface electrodes. Higher-frequency components are commonly seen with intramuscular recorded signals due to the potent low- pass filtering effect of soft tissue (Kamen and Caldwell, 1996). In most circumstances, however, surface electrodes can be used for fatigue studies.

The geometric arrangement of the electrode plates is especially important when determining muscular fibre conduction velocity (Lindstrom and Petersen, 1981). The SEMG electrode array should be placed parallel to the muscle fibre direction to avoid the motor point (Linssen et al., 1993). When the electrode array is placed perpendicular to the muscle fibres, a loss in amplitude can occur.

Filter settings

The amplifier needs to have frequency bandpass characteristics that match or exceed the signal bandwidth. Skin, electrode, and cable movement can cause low-frequency noise, but the noise is usually limited to < 10 Hz. With a proper high-pass filter setting, the noise can usually be reduced without significant attenuation of the EMG signal. The low-pass filter should have a cut-off at or just above the Nyquist limit (one-half the sampling rate) (Kamen and Caldwell, 1996). Keeping these guidelines in mind, bandpass ranges may vary slightly in different protocols such as 8 Hz to 800 Hz (Hary, Belman, Propst and Lewis, 1982) and 5 Hz to 500 Hz (Linssen et al., 1993).

Amplifiers

The amplifier used for surface myoelectric signal processing should meet several general specifications, including an input impedance of 100 to 1000 MΩ. It also is important to have sufficient gain to produce an output of approximately 1 V. Input bias and offset currents less than 50 pA to 100 pA are recommended (Merletti et al., 1984; Merletti and De Luca, 1989).

Reproducibility

The reproducibility of SEMG is questioned by some investigators. By maintaining good technique, however, SEMG measurements are reproducible. Merletti (1998) examined the repeatability of electrically evoked EMG signals in the human vastus medialis muscle. He found that the mean and median frequencies were the only variables with acceptable repeatability. The repeatability of conduction velocity was not found to be sufficient for clinical application.

The reproducibility is improved for both voluntary and electrically evoked signals by maintaining similar electrode placement and alignment between sessions (Merletti and De Luca, 1989).

Crosstalk

Crosstalk occurs when a signal generated by given muscle is detected above a different muscle (Merletti et al., 1992a). With surface electrodes, the recording represents the same depth and breadth of the motor unit despite the muscle's size. With small muscles, the signal is theoretically more representative of the muscle. The potential for crosstalk, however, is increased with very small muscles (Kamen and Caldwell, 1996).

Contraction type

Sustained isometric contractions are ideal for studies of muscle fatigue because they allow for easily controlled experimental conditions (Merletti et al., 1992a). Although intermittent contractions are more common in everyday life, dynamic changes occur when the muscle contracts and relaxes. Blood flow to the muscle fluctuates during the contraction, as does the removal of metabolites (Merletti et al., 1992a). These variables contribute to the spectral changes;

therefore, conclusions regarding spectral changes that occur with a sustained isometric contraction are valid only for this type of contraction.

EMG to force ratio

The changes in the EMG/force ratio point to two types of fatigue: an increased EMG/force ratio is classified as "peripheral" fatigue, and a constant EMG/force ratio associated with a force decrease is classified as "central" fatigue. The type of fatigue obtained in the present study for the power producer muscles is peripheral fatigue. It may result from a lack of force generation capacity by the whole muscle, involving impaired neuromuscular transmission and impaired excitation-contraction coupling. The increased EMG/force ratio of power producer muscles may be attributed to the changes in contractile process after repeated sprints, as found previously (Balsom, Seger and Ekblom, 1992).

It has been shown for many muscles that as fatigue occurs in a sustained submaximal isometric contraction, the rectified-integrated EMG signal increases in amplitude in order to maintain the same force output (Edwards and Lippold, 1956; Kadefors, Kaiser and Peterson, 1968; Vredenbregt and Rau, 1973; Stulen and De Luca, 1978). This increase in amplitude is more pronounced near the end of a sustained contraction, and is a result of either recruitment (Edwards and Lippold, 1956) rate modulation (Lippold et al., 1960) or synchronisation (Milner-Brown, Stein and Lee, 1975).

The relationship between the amplitude of the EMG signal to the force output of the muscle in a non-fatigued state has been described by some to be linear (Stephens and Taylor, 1972; Milner-Brown et al., 1975), while others have described it as non-linear (Komi and Buskirk, 1970).

Lawrence & De Luca (1983) found that the relationship varied between different muscles, although it generally tended to be close to linear and was independent of the state of training of the muscle and its force output. They suggested that some factors, which may account for these differences between muscles, are:

- Motor unit recruitment and firing rate properties.
- The distribution and quantity of slow-twitch and fast-twitch fibres within the muscle.
- Cross talk from adjacent muscles.
- Agonist-antagonist muscle interaction.

Increasing force output by means of an increase in firing rate (rate modulation) provides a linear relationship to the EMG amplitude, whereas recruitment does not (De Luca and Van Dyk, 1975). The balance of these two mechanisms depends on the muscle concerned. It is also thought that at low force levels (30-50% MVC) recruitment is dominant in small muscles (e.g. first dorsal interosseous muscle), and that rate modulation becomes more important with increasing force (Freund, 1983). However, as force increases it becomes more difficult to assess the relative roles of these two mechanisms, particularly because action potentials of different motor units begin to overlap as force increases (Weytgens and Van Steenberghe, 1984).

Lawrence & De Luca (1983) state that the amplitude of the action potential of a single fibre is proportional to its diameter. As fast twitch fibres are generally larger than slow twitch fibres, they will have higher amplitude action potentials and a higher amplitude root-mean-square (RMS) EMG signal. However, the amplitude contribution depends on the distance between the motor unit and the recording electrode and so fibre distribution becomes relevant. One must also take into consideration the "size principle" which says that larger motor units are recruited at higher force levels (Henneman and Olson, 1965).

Muscle fatigue and blood pressure

When a motor command is sent to a muscle, a parallel command is sent to cardiovascular centres in brainstem, and will cause increase cardiac output and central blood pressure (Korg and Lindhard, 1913; Goodwin, McCloskey and Mitchell, 1972). For moderate intensity isometric exercise, this central command explains most of the pressor response (Gandevia and Hobbs, 1990; Pawelczyk, Warberg, Mitchell and Secher, 1997). In addition to the central pressor response, chemoreceptors within the muscle detect the build up of metabolites and act through cardiovascular centres to produce a muscle reflex that increases blood pressure (Iwamoto, Mitchell, Mizuno and Secher, 1987). A component of this muscle reflex may also rise from muscle reflex mechanoreceptor afferents (Kaufman, Longhurst, Rybicki, Wallach and Mitchell, 1983). The relative effect of the muscle reflex is likely to be greater for higher intensity exercise (Seals, 1989; Gandevia and Hobbs, 1990). Exercise can involve two sorts of muscle activity: isometric (or static) contractions and dynamic (or rhythmic) contractions. In general, isometric contractions result in an increase in total peripheral resistance and increase in heart rate so that there is often a large increase in mean arterial blood pressure. Dynamic exercise is accompanied by a decrease in total peripheral resistance, and an increase in stroke volume and heart rate, so that there is a large increase in cardiac output but mean arterial pressure only rises modestly (Coote, 1995).

Johnson et al. (1973) investigated the effect of changes in muscle perfusion pressure on the performance of adductor pollicis, a muscle comprised primarily of slowly fatiguing type I fibres. At low workloads, muscle performance is sensitive to changes in perfusion pressure across the physiological range (75-125 mmHg). As perfusion pressure falls, force output decreases and it increases as perfusion pressure rises (Fitzpatrick, Taylor and McCloskey, 1996).

The dependence of muscle performance on muscle perfusion suggests a feedback control that could regulate the central pressor response. As force output falls through fatigue or changes in perfusion, centrally generated motor command signals would increase if a voluntary attempt were made to maintain force output. Muscle performance could be restored if these centrally generated commands evoked an increase in central blood pressure and if that resulted in an increase in local perfusion pressure and blood flow to active muscle. The increase in local perfusion pressure and blood flow will improve muscle performance (Fitzpatrick et al., 1996). Muscle performance is strongly affected by physiological changes in central blood pressure and suggest that sensory input concerning the adequacy of muscle performance exerts a feedback control over the increase in systemic blood pressure during muscular activity (Wright, McCloskey and Fitzpatrick, 2000).

The effect of ageing on fatigue characteristics

Muscle size and related neuromuscular function change dramatically across the human lifespan, initially showing rapid increases due to growth and then later more gradual decreases due to ageing. Whereas the initial stage of development contains tremendous increases in the number of muscle fibres before birth, later growth occurs primarily by enlargement of size in the postmitotic muscle cells. During adolescence there is a pubertal growth spurt and the associated marked increase in serum testosterone in males results in a notable gender difference in lean tissue mass and strength, particularly for the upper body (Tanner, 1990). The stage of young adulthood in the 20s and early 30s involves a period of peak musculoskeletal function, middle age in the 40s and 50s involves some slowing of contraction, but changes in absolute muscle strength are minor until about the sixth decade of life (Porter, Vandervoort and Lexell 1995).

Research into children (6-16 years) muscle composition has been rare. The invasive procedures (biopsy) raise ethical concerns, whereas less invasive procedures (magnetic resonance imaging and spectroscopy) have yet to be applied to children (Cooper and Barstow, 1996). Although it is not certain, it appears that fibre type differentiation occurs early in life. By the age of 6 year, the distribution of muscle fibre type is similar to that of young adults

(Mero, Jaakola and Komi, 1991). Bell et al. (1980) suggested that other ultra-structural skeletal muscle properties differ minimally between children and young adults. Despite similar muscle composition, the ability to produce tension proportional to muscle cross-sectional area is lower in children than adults (Kanehisa, Ikegawa, Tsunoda and Fukunaga, 1994a). Comparison of evoked and voluntary muscle activation has led to the suggestion that under voluntary conditions boys are unable to stimulate their motor unit pool fully, typically utilising just 80% (Blimkie, Ramsay, Smith, MacDougall, Sale and Garner, 1989; Ramsay, Blimkie, Smith, Garner, MacDougall and Sale, 1990). Resistance training studies in children have also determined that regular stimulus enhances the ability to generate muscle tension through improved neural adaptation rather than an increase in muscle cross-sectional area (Blimkie et al., 1989; Ramsay et al., 1990). These issues need careful consideration when selecting a muscle function assessment procedure and interpreting the results. In situations where longitudinal assessment is required, for example monitoring the progression of rehabilitation, neural adaptations may be the cause of change rather than variation in muscle cross-sectional area.

Despite extensive research on age-related changes in neuromuscular morphology and function (Roos, Rice and Vandervoort, 1997; Luff, 1998), fatigue studies in elderly humans have been few in number, providing limited insight into age-related alternations in fatigue and recovery mechanisms. Most studies have tested fatigue using intermittent maximal contractions, and results suggest there is no clear difference in fatigability between young and old individuals

(Lindstrom, Kadefors and Petersen, 1977; Hicks, Cupido, Martin and Dent, 1992; Bemben, Massey, Bemben, Misner and Boileau, 1996).

Various changes take place in the neuromuscular systems with normal ageing. Example of specific changes that have been observed in ageing humans and animals include: the loss (Lexell , Sjostrom and Tylor, 1988) and atrophy, mostly type II, of muscle fibres (Protor, Sinning, Walro, Sieck and Lemon, 1995), a decrease in the number of motor neurones/ motor units (Brown, Strong and Snow, 1988), a process of denervation and reinnervation of muscle fibres (Pettigrew and Noble, 1991), changes in muscle metabolism (Boaro, Soares and Konig, 1998), the slowing of muscle contractile properties (Vandervoort and McComas, 1986), alterations at the neuromuscular junction (Boaro et al., 1998), changes in voluntary activation (Harridge, Kryger and Stensgaard, 1999) and motor unit activity (Laidlaw, Bilodeau and Enoka, 2000). However, the specific consequences of these changes in the motor function of older individuals remain unclear.

Around the age of 40, healthy human subjects begin to lose muscle force generation capacity (Bemben, Massey, Bemben, Misner and Boileau, 1991; Merletti, Lo Conte, Cisari and Actis, 1992b; Thompson, 1994). The loss of maximum isometric force during ageing varies among different muscle groups, being higher in the lower limb than the upper limb (McDonagh, White and Davies, 1984). McDonagh et al. (1984) reported a difference in maximal isometric force of about 40% in the triceps surae muscle and of only about 20% for the elbow flexors between the age of 26 and 71 years. The cause of this variation in force decline among different muscles is unknown. Asmussen (1980) suggested that the reduced use of lower extremities compared with the upper limbs is responsible. Loss of strength can be reduced in elderly people who participate in sports and is reversed by physical activity (Brown, McCartney and Sale, 1990; Welsh and Rutherford, 1996).

The physiological changes underlying the loss of muscle strength are not fully understood. Progressive muscular weakness is associated with a shrinking of muscle mass and muscle cross-section. The loss of muscle mass is greater in muscles with predominantly type II fibres (Campbell, McComas and Petito, 1973; Lexell, Henriksson-Larsen and Sjostrom, 1989). Motor unit (MU) remodelling (i.e., denervation and renervation of the MUs) also occurs with ageing, so that type II fibres are reinnervated by collateral sprouting of axons innervating the slow MUs (Albert, 1984; Brown et al., 1988). It has been suggested that such type II fibres become slow fibres. The differences in force decline observed in different muscle groups seem to be reflected in the extent of age-related changes in fibre size and in the proportion of fibre types in different muscles. For example, the reduction of type II fibre size with age is more evident in the vastus lateralis than biceps brachii muscle (Aniansson, Hedberg, Henning and Grimby, 1986). The result of these changes is a shift toward a more uniform and slow muscle fibre content, with progressively fewer large fibres (Larsson, 1978).

Hara et al. (1998) found no differences in muscle fibre conduction velocity decrement during voluntary contractions of the abductor digiti minimi in young and elderly subjects, and explained the finding on the basis of the ischaemic condition of the muscle during the contractions. In the case of voluntary contractions, other aspects, related to central control, have to be taken into account, such as changes in MU firing rates, substitution and synchronisation.

These phenomena suggest that elderly subjects should show a paradoxically higher resistance to fatigue and longer endurance time. This has been partially confirmed in the past, although, surprisingly, there has been little research on differences in fatigability between young and elderly subjects.

These phenomena suggest that elderly subjects should show a paradoxically higher resistance to fatigue and longer endurance time. This has been partially confirmed in the past, although, there has been little research on differences in fatigability between young and elderly subjects. Some investigators have reported higher fatigability in elderly subjects during electrically elicited contractions (Davies, Thomas and White, 1985; Lennmarken, Bergman, Larsson and Larsson, 1985), others found lower fatigability (Narici, Bordini and Cerretelli, 1991), and others found no age-related change in muscle fatigability (Klein, Cunningham, Peterson and Tylor, 1988; Merletti et al., 1992b) or endurance during voluntary contractions (Porter et al., 1995)

Differences in the fatigability of females and males

Males tend to have larger muscles and greater absolute strength than females (Maughan, Watson and Weir, 1983; Kaneshia, Ikegawa and Fukunaga, 1994b). Furthermore, recent improvements in the technology used to assess body composition, such as magnetic resonance imaging and ultrasonography, have made the measurement of both the size and fibre pennation angle of human muscles possible (Abe, Brechue, Fujita and Brown, 1998; Ichinose, Kaneshia, Ito, Kawakami and Fukunaga, 1998; Chow, Medri, Martin, Leekam, Agur and McKee, 2000). Abe et al. (1998) reported that the gender differences in pennation angle appeared to be related to differences in muscle size. Ichinose et al. (1998) stated that the difference in the ability to generate force in the triceps brachii muscle might, in the main, be attributed to gender difference in muscle size rather than to architectural characteristics.

Force generation in its early stages requires time, mostly for the stretching of the series elastic component in the muscle-tendon complex. This time is called electromechanical delay, and it can be defined as the time lag between the onset of electromyographic (EMG) activity and tension (Komi, 1984) some previous studies have demonstrated that there are differences in the electromechanical delay between men and women (Bell and Jacobs, 1986; Winter and Brookes, 1991). For example, Winter and Brookes (1991) reported that the electromechanical delay in women (44.9 ms) was significantly longer than in men (39.6 ms). These findings indicate that there are differences in the elasticity of the muscle-tendon complex between men and women. However, there have been no reports so far regarding the gender differences in tendon properties in humans.

Females generally have longer endurance time than males especially at low to moderate forces (Kahn, Kapitaniak, Huart and Mond, 1986; Zijdewind and Kernell, 1994; West, Hicks, Clements and Dowling, 1995). For example, the endurance time of women was longer than that of men when performing an isometric contraction at 20% of maximum voluntary contraction with knee extensor muscles but not at 50 or 80% of MVC. Similarly, women were able to perform a greater number of repetitions with the elbow flexor muscles when lifting loads that were 50, 60, and 70% of maximum but not with loads that were 80 or 90% of maximum (Maughan, Harmon, Leiper, Sale and Delman, 1986). This sex difference also has been observed in adductor pollicis (Fulco, Rock, Muza, Lammi, Cymerman, Butterfield, Moore, Braun and Lewis, 1999; Ditor and Hicks, 2000) and extrinsic finger flexor (Petrofsky, Burse and Lind, 1975; West et al., 1995). The mechanism for this difference in endurance time is unknown. A common explanation has been that men, who are usually stronger, sustain greater absolute force when target force is based on an individual's strength (Carlson, 1969; Miller, MacDougall, Tarnopolsky and Sale, 1993; Fulco et al., 1999). Indirect evidence suggests that greater absolute forces are associated with increased intramuscular pressures, occlusion of blood flow, accumulation of metabolites, heightened metaboreflex responses and impairment of oxygen delivery to the muscle (Barnes, 1980; Sadamoto, Bonde-Petersen and Suzuki, 1983; Sejersted, Hargens, Kardel, Blom, Jensen and Hermansen, 1984). Furthermore, activation of the metaboreflex, as measured by the rate of increase in the mean arterial pressure (MAP) and heart rate (Mitchell, Kaufman and Iwamoto, 1983; Rowell and O'Leary, 1990), is inversely related to endurance time (Seals, 1989; Fallentin and Jorgensen, 1992; Seals, 1993). Accordingly, women had longer endurance times when performing low-intensity contractions with the knee extensor muscles, but this difference disappeared during high-intensity contractions when both men and women would experience circulatory occlusion (Maughan et al., 1986).

The endurance times of submaximal contractions that involve multiple muscles, however, could also be influenced by variation in the pattern of muscle activation (Sjogaard, Kiens, Jorgensen and Saltin, 1986; Fallentin, Jorgensen and Simonsen 1993; Kulig, Powers, Shellock and Terk, 2001) [Perhaps including differences between men and women (Semmler, Kutzscher and Enoka, 1999)]. Hunter and Enoka (2001) found that the endurance time of women was greater than that for males and that endurance time was inversely related to the absolute force sustained during the contraction. This difference in endurance time was accompanied by similar increase in electromyogram (EMG) during the fatiguing contraction for males and females but by a reduced pressor response for females.

Aims of investigations:

Fatigue is a common symptom in many neurological complaints. Consequently, it is important to investigate fatigue processes in relation to different factors such as age and sex. Surprisingly there are no published studies in the literature about fatigue in children under age of 10. So no comparison between children and old people has yet been possible. In fatigue studies there are still unanswered questions about the development of fatigue in relation to age and sex. The experiments conducted in this study were designed to address the following aims:

1- To study the relationships between mean median frequency of the EMG spectrum and the age and sex of the volunteers.

2- To investigate the relationship between the time to voluntary force failure and the age and sex of the volunteers.

3- To study the relaxation rate after contractions in different age groups of females and males.

4- To investigate the blood pressure and heart rate changes during fatiguing contractions in females and males in different age groups.

CHAPTER 2

General Methodology

Experimental volunteers

108 volunteers participated in this study. There were 53 females and 55 males. The age of the volunteers ranged from 5 to 65 years.

The youngest female was 5 and the oldest was 54. The youngest male was 5 and the oldest was 65 years of age. A brief medical history was taken. All volunteers were healthy, with no history of neurological disease or musculoskeletal abnormality.

All volunteers gave their informed consent in accordance with a protocol approved by Glasgow University research ethics committee. All volunteers were informed that they were free to terminate the test at any time should they wish. Each volunteer participated in a single experimental session. Before tests were performed on minors, the parents gave consent. The parents were present throughout the tests.
A series of experiments were performed to investigate the fatigue process during grip contractions.
The main aim of this project was to investigate sex, age and cardio vascular system related changes during muscle fatigue. To facilitate this, the volunteers were divided into 6 age groups. Details are shown in table 2.1.

Group	Age range	Female N*	Male N*	Female mean age	Male mean age
1	5 to 9	5	5	7.6	7.2
2	10 to 19	13	13	12.9	12.6
3	20 to 29	9	9	22.6	22.2
4	30 to 39	10	10	33.4	35.4
5	40 to 49	10	10	43.2	44.6
6	> 50	6	8	52.2	57.8

Table 2.1 shows the age range and the mean age of females and males. * Number of volunteers in each age group.

Volunteers for all studies were recruited by an advertisement in University of Glasgow and local schools. It was possible to match the numbers of males and females in each age group.

Prior to each experiment, the height and weight of volunteers were measured. They were seated comfortably on a chair for 15 minutes before their resting blood pressure and heart rate were measured once (Figure 2.1). Blood pressure and heart rate (before and immediately after contraction) were measured by the OMRON digital blood pressure monitor (model HEM-705 CP).

During this period the purpose of the project and the type of contractions required were described to them.

The dominant or preferred forearm of the volunteer was always chosen for the experiments.

Figure 2.1 shows the experimental set up prior to the experiment. The subject was seated comfortably on a chair for 15 minutes before their blood pressure and heart rate were measured. Blood pressure and heart rate (before and immediately after contraction) were measured by the OMRON digital blood pressure monitor (model HEM-705 CP).

Force

The force developed during isometric contractions of finger flexors was measured with a strain gauge. The span of the strain gauge and the height of the table were adjusted for the most comfortable position for each volunteer. Each volunteer had an opportunity to become familiar with the experiment by making up to 10 contractions about 20% to 30% of maximum voluntary effort. Volunteers were asked to perform three maximum isometric contractions, each of which should be maintained at least for two seconds (Edwards et al., 1977). The force generated during a maximum voluntary effort (MVE) was measured. The greatest force was identified as the maximal voluntary effort and then the submaximal contractions were expressed as percentage of MVE. The volunteers were asked to perform isometric contractions at 20%, 40%, 60% and 80% of MVE the duration of each contraction was 5 seconds. After another demonstration and confirmation that the volunteer understood the task, the volunteer was then required to hold the force level within a band of 60-65 % of MVE for as long as possible. Target forces were indicated on the monitor screen to provide visual feedback for the volunteers (Figure 2.2). In addition to visual feedback verbal encouragement was given continuously by experimenter to persuade the volunteers to maintain the required force as long as they could.

Figure 2.2 shows the experimental set up for the experiments. The volunteer was required to hold the force level within a band of 60-65 % of MVE for as long as possible. Target forces were indicated on the monitor screen to provide visual feedback for the volunteers.

The trial was considered finished when the level of force fell below the 60% MVE level at any time after the initiation of the trial. This was performed once for each volunteer. It was assumed that 10 minutes rest was adequate for recovery (Miller et al., 1995). The median frequency of the EMG recovers within 4-5 minutes after a sustained contraction (Sabbahi, Deluca and Powers, 1979). The conduction velocity of the muscle fibres to recover (Broman, 1977) linearly related to median frequency (Stulen and De Luca, 1981). In particular the median frequency, the frequency that divides the area of the calculated spectrum in half, of the EMG was calculated for the first and last 5 seconds of each sustained contraction. In the case of the intermittent contractions, the median frequency of each 5 seconds of activity was calculated. In both females and males there was a substantial reduction in median frequency. This indicated a strong fatigue state. The reduction in median frequency is similar in both females and males. The same group of volunteers also participated in the intermittent contraction experiment. This was carried out after the sustained contractions and after a recovery period of 10 minutes chapter 3 (page 65).

The median frequencies of the first and last contractions in both sustained and intermittent contractions are shown in table 2.2.

The initial median frequencies were slightly higher in the later experiment. This suggests that recovery was complete. At volitional exhaustion the median frequency was reduced to 72 Hz for females and 68 Hz for males. This was substantially higher than the median frequency just before failure in sustained contractions.

Median frequency	Females Mean ± SEM	Males Mean ± SEM	P value t-test
First 5 seconds sustained	84.5 ± 1.9 (Hz)	86.1 ± 2.4 (Hz)	0.597
Last 5 seconds sustained	48.30 ± 2.8 (Hz)	49.4 ± 2.9 (Hz)	0.775
First 5 seconds intermittent	88.6 ± 1.8 (Hz)	89.3 ± 2.6 (Hz)	0.834
Last 5 seconds intermittent	71.8 ± 2.2 (Hz)	67.9 ± 2.9 (Hz)	0.282

Table 2.2 shows the median frequencies of the first and last contractions in both sustained and intermittent contractions. The columns represent the mean ± SEM of the 53 female and 55 male volunteers. The initial median frequencies were slightly higher in the later experiment. This suggests that recovery was complete.

After 10 minutes rest and another demonstration and confirmation that the volunteer understood the task, the volunteers were asked to perform intermittent contractions 5 seconds contraction and 5 seconds rest at the same level of force as long as they could. Target forces were indicated on the monitor screen to provide visual feedback for the volunteers. In addition verbal encouragement was given continuously by experimenter to persuade the volunteers to maintain the required force as long as they could.

The test procedure was simple and did not require any practical trial prior to the main test. This also prevents any possible fatigue in the volunteers.

Calibration

The strain gauge and associated amplifiers were calibrated by using known weights. The graph (2.3) below shows these data and confirms the linearity of the system up to 1000 N. This is more than 10% greater than the largest grip forces measured.

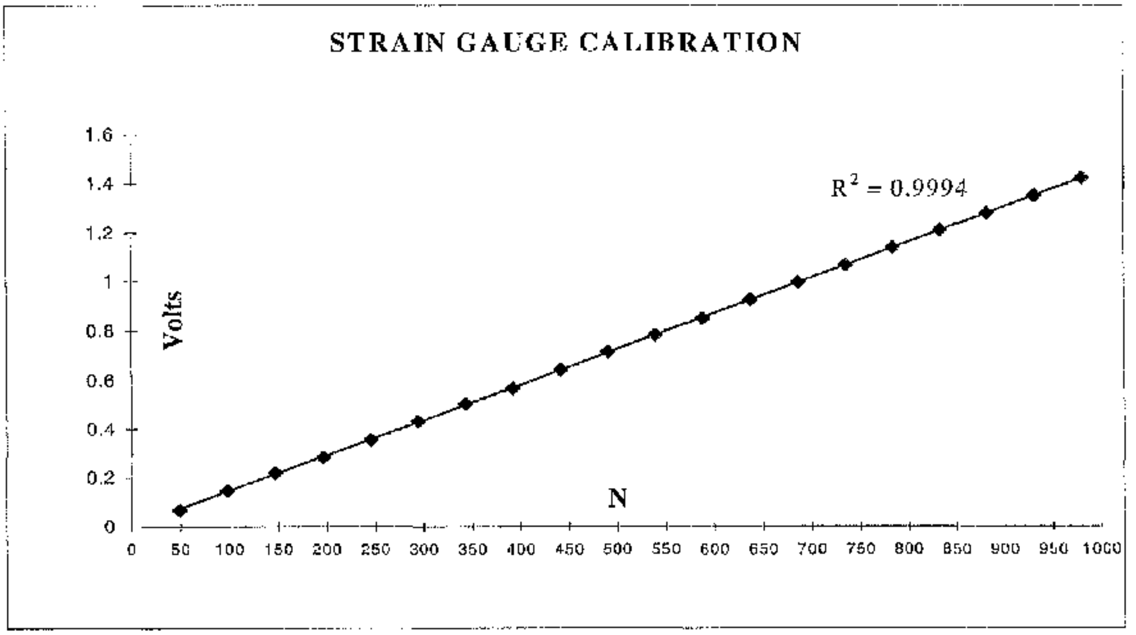


Figure 2.3 shows the calibration curve of the strain gauge.

Anatomy

The main muscles in the anterior compartment of the forearm are shown (below) in table 2.3 (Johnston and Whillis, 1949; Gosling, Harris, Humpherson, Whitmore and Witton, 1993):

Muscle	Origin	Insertion	Function
Flexor carpi radialis (radius-wrist flexor)	Medial epicondyle of humerus	Base of the second and third metacarpal bones	Bends the elbow. When acting alone it flexes the wrist. Can also assist in pronating the forearm and hand
Palmaris longus	Medial epicondyl of the humerus	Palmar aponeurosis	Flexes the hand
Flexor carpi ulnaris (ulna-wrist flexor)	Medial epicondyle of humerus, and olecranon process of ulna	The pisiform, hamate, and fifth metacarpal bones	When acting alone it flexes the wrist and, by continuing to contract, it bends the elbow
Flexor digitorum superficialis (superficial finger flexor)	Medial epicondyle of humerus, medial surface and coronoid process of ulna, and shaft of radius	By four tendons onto middle phalanges of each finger	Bends the elbow and fingers. Assists in flexing the wrist radius
Flexor digitorum profundus	Shaft of ulna	Of each finger by four tendons, onto terminal phalanges	Flex the phalanges and the hand

Table 2.3 shows the muscles that affect forearm.

Other muscles, such as the brachioradialis, the pronator teres, the pronator quadratus and felxor policis longous, and some of the muscles in the posterior compartment of the forearm also act as weak flexor of the wrist and assist in dynamic wrist flexion exercise.

Muscles that are significant contributors of power grip formation are the extrinsic muscles of the hand (Grabiner, 1989). A prime finger flexor, and consequent grip forming muscle, is the flexor digitorum superficialis muscle (Gray, 1985).

Electromyogram

The skin lying over the anterior compartment of forearm was prepared for EMG recording by light abrasion and cleansing with isopropyl alcohol BP 70%. Two 9 mm silver / silver chloride electrodes with a fixed interelectrode distance of 2 cm centre to centre were used. The flexor digitorum superficialis muscle was identified by asking the volunteer to flex the fourth finger against an external resistance while visually observing and palpating the forearm over the contracting muscle. The electrode set was placed over the belly of the flexor digitorum superficialis muscle, parallel to the assumed longitudinal axis of the muscle fibres (Figure 2.4). To improve the conductivity, Signa cream was used. This is a highly conductive cream electrolyte, which specially formulated to produce superior conduction between skin and electrodes was used. 3M Micropore surgical tape 2.5 cm was used to secure the electrodes. Connector cables were 75 cm long.

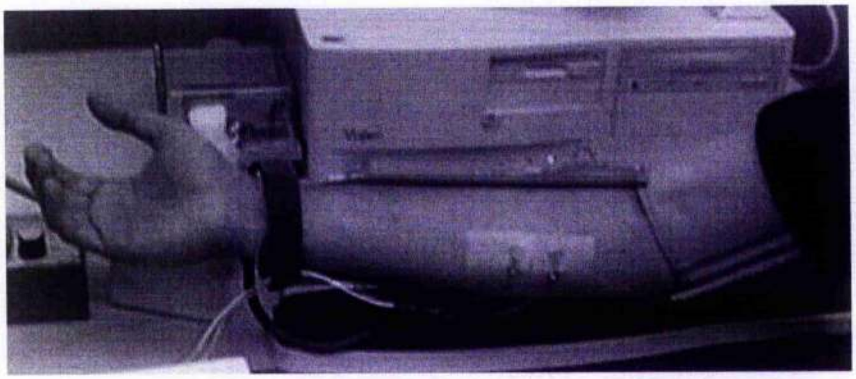


Figure 2.4 shows the location of the recording electrodes of EMG on the belly of the flexor digitorum superficialis muscle. Two 9 mm silver / silver chloride electrodes with fixed interelectrode distance of 2 cm centre to centre were used. The ground electrode was an electrode pad was a strap, 2 cm broad, wrapped round the wrist and held in place by a Velcro retaining strap.

The volunteers were not allowed to curl their fingers during this test. This reduces the possibility that the flexor digitorum profundus, which inserts into the distal phalanges, could make a major contribution to the EMG signal. To ensure that the flexor carpi radialis muscle, a wrist flexor did not contribute significantly to the EMG, electrode placement was considered appropriate when the EMG signal was present during finger flexion with a voluntary stable wrist, yet absent during wrist flexion with no voluntary finger flexion. The position of the hand remained constant. The wrist was kept in a neutral position because it has been shown that grip strength can be dependent on wrist position (Hazelton, Smiddt and Flatt, 1975).

The EMG signal was conditioned using a Neurolog NL 850 isolated preamplifier and Neurolog NL 106 AC/DC amplifier. The total gain was X100. The signal was band pass filtered between 10 – 500 Hz using Neurolog NL 125. A 50Hz notch filter could be switched on in the circuit when appropriate. The pre-amplifier was placed close to the volunteer so as to keep the wires from the EMG electrodes as short as possible.

An A/D converter digitised the EMG and force signals (CED 1401 micro interface) CED Cambridge at sampling rate of 1000 Hz and 100 Hz respectively and stored in a PC. The signals were analysed using Spike 2 software version 3.15.

These allow adequate resolution of time and voltage for the purpose of this experiment.

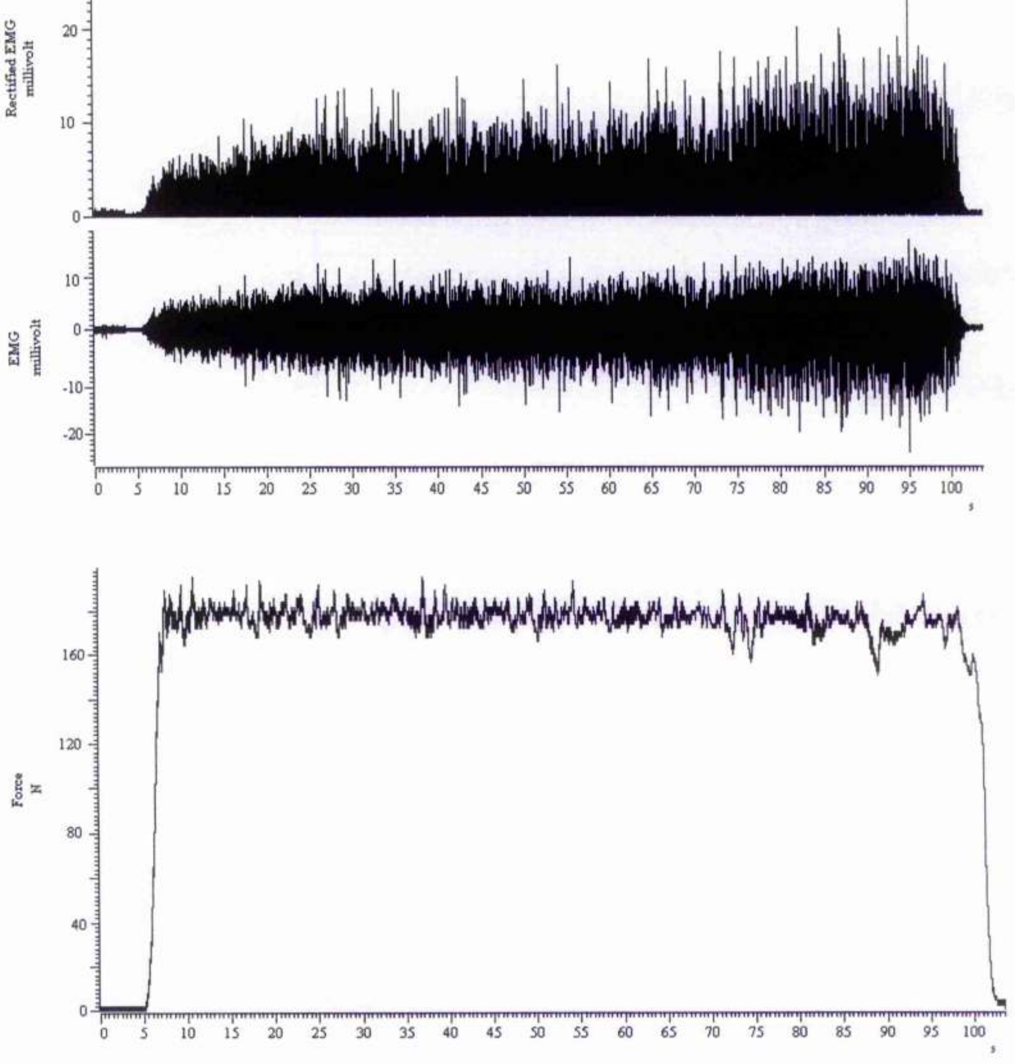


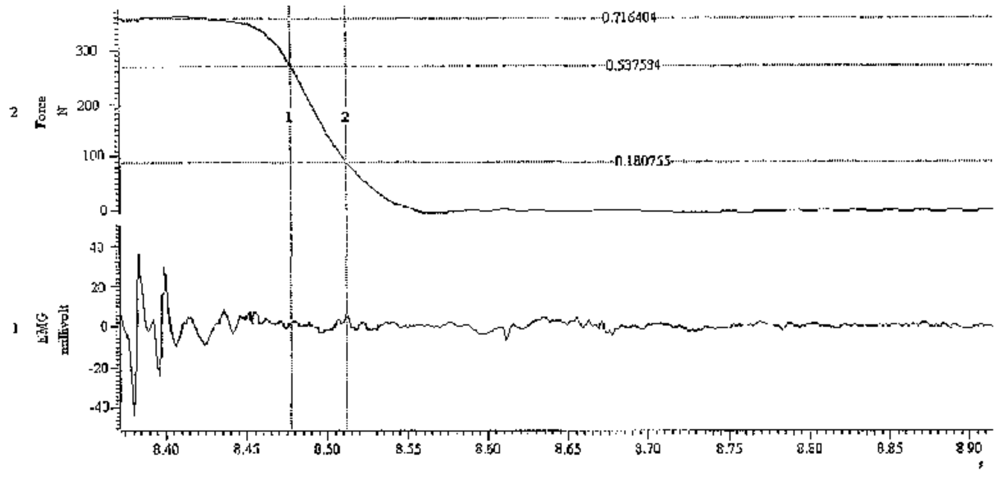
Figure 2.5 shows EMG and force records from finger flexor muscles. The increase in rectified EMG can be seen.

Half relaxation time

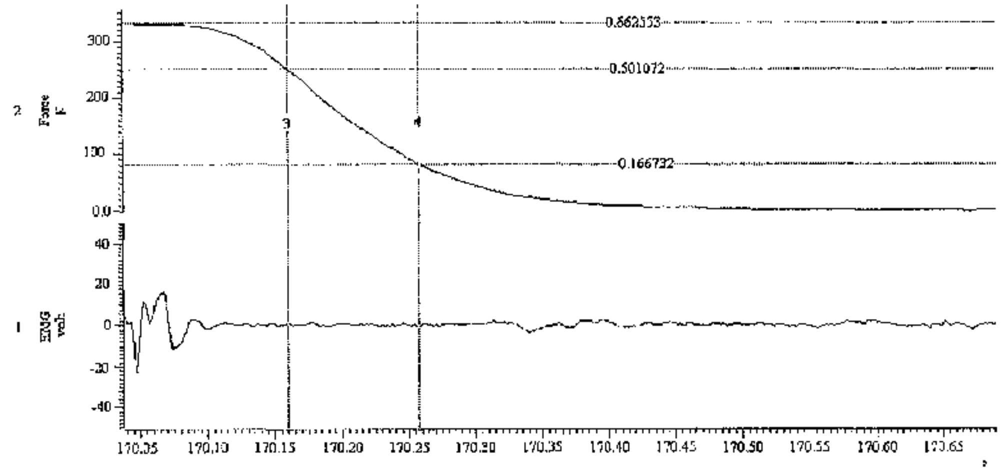
In order to measure relaxation rates, data from the whole period of the experiment was captured at a sampling rate of 1000 Hz for EMG and 100 Hz for force. It was possible to display one EMG channel and force channel in order to determine the time from which the half relaxation time should be measured; this measurement was taken from when the EMG activity ceased (Figure 2.6). The signal was expanded considerably on the computer screen in order to measure time accurately.

The time for half relaxation of grip force was assessed by determining the time taken for the force to fall from 75 to 25% of 60% of MVE at the end of contractions (Lyons and Aggarwal, 2001). The first and last contractions were measured.

These were measured using the spike 2 software version 3.15.

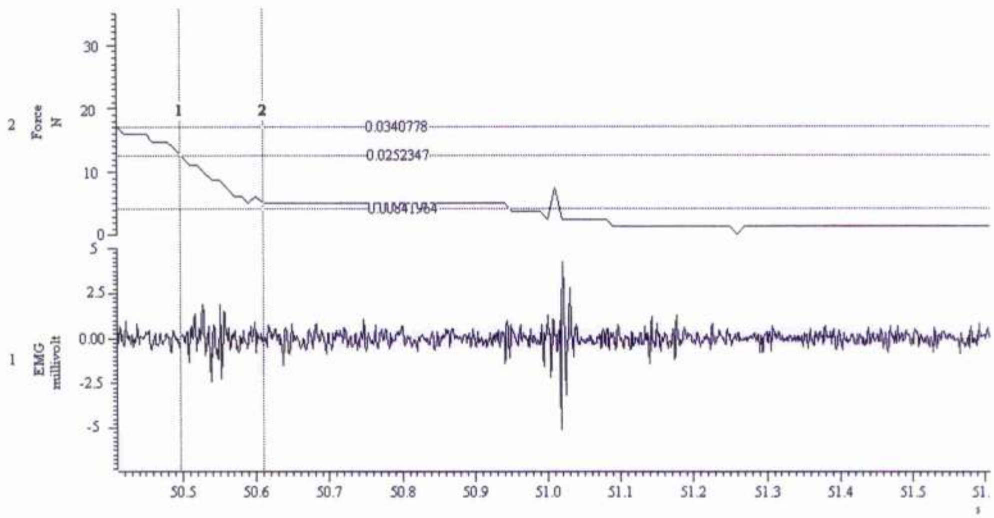


(A)

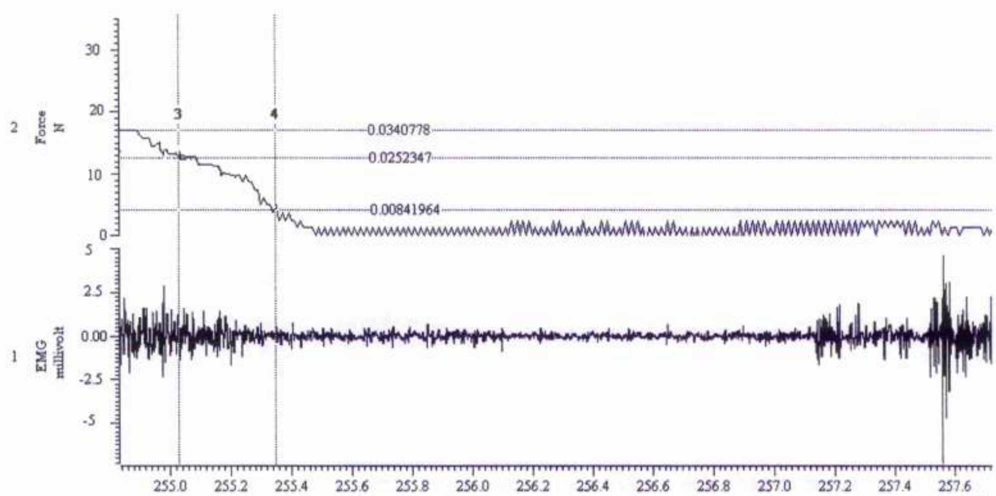


(B)

Figure 2.6 shows the measurement of half relaxation time in a volunteer with a clean EMG at the end of contraction. (A) shows the first contraction of a series of intermittent contractions and (B) shows the last contraction (fatigued muscle). The time between cursors' 1and 2 are 35ms (A) and between cursors 3 and 4 is 99 ms (B).



(A)



(B)

Figure 2.7 shows the measurement of half relaxation time in a volunteer with some on-going EMG at the end of contraction. (A) shows the first contraction of a series of intermittent contractions and (B) shows the last contraction (fatigued muscle). The time between cursors 1and 2 is 111ms (A) and between cursors 3 and 4 is 318 ms (B).

Statistical analysis

The normality of data was tested using the one-sample Kolmogrov-Smirnov test. The differences between age groups in relation to various parameters were evaluated by a one-way ANOVA test. In addition a Tukey's HSD (honestly significant difference) post-test was used to calculate multiple comparisons. The results are presented as means and standard error of mean. The statistical significance was assumed at the level of $P < 0.05$.

These analyses were carried out using SPSS version 11.

CHAPTER 3

Results

3.1 Characteristics of volunteers

A series of experiments was performed to investigate the fatigue characteristics in hand grip of 108 volunteers, 53 female and 55 male. Their ages were 5 – 65 years. The aim of this chapter was to investigate sex and age related changes. To facilitate this, the data were divided into 6 age groups. Details are shown in table 3.1.1.

Group	Female weigh Mean ± SEM	Male weight Mean±SEM	Female height Mean ± SEM	Male height Mean±SEM	Female MVE Mean ± SEM	Male MVE Mean ± SEM
1	32.6±4.8	25.6±2.1	1.31±0.05	1.3±0.05	136.8±32.7	140.2±24.2
2	48.4±2.9	47.8±2.8	1.55±0.03	1.57±0.03	233.5±22.1	254.2±29.7
3	62.8±1.7	75.3±3.2	1.69±0.03	1.78±0.02	368.9±23.5	585.1±31.8
4	62.6±3	80.4±5	1.66±0.02	1.76±0.02	308.8±19.3	528.5±26.3
5	66.6±3.7	85.9±4.8	1.62±0.02	1.79±0.03	294.5±18.2	514.0±24.9
6	60±6	86±4.5	1.64±0.03	1.82±0.03	275.4±21.3	520.2±37.3
Average	56.8±2	68.7±3.2	1.60±0.02	1.69±0.02	278.1±11.1	435.9±22.9

Table 3.1.1 shows the mean weight (kg), height (m), MVC (N) and their average of females and males. The columns represent the 53 female and 55 male volunteers in 6 different age groups.

Statistics

The initial analysis compared pooled data for all male and female volunteers. One-sample Kolmogorov-Smirnov tests confirmed that these data were normally distributed.

A full list of measurements and their changes is shown in appendix 1.

In a pilot study a series of experiments were performed on 24 volunteers (12 females and 12 males) to measure how long a continuous contraction could be maintained. After assessment of each individual's maximum force, they were asked to maintain contractions at 20, 40, 60, 80% of maximum started by 80%. Rest intervals of 10 minutes were allowed between each contraction (chapter 2 page 47).

These data are shown in figure 3.1.1. It can be seen that the duration of contractions increases as the force is reduced. It is interesting to note that at each force the female volunteers continued the contraction for significantly longer periods.

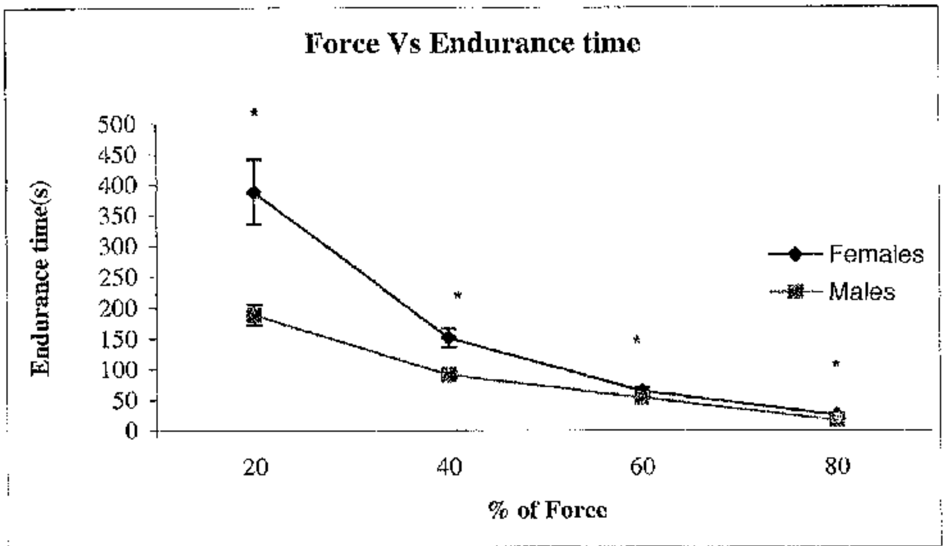


Figure 3.1.1 shows the relationship between force and endurance time at different 20, 40, 60, 80% of MVE in dominant arm in females and males. The points represent the mean ± SEM of the 10 female and 10 male volunteers. The mean female endurance time was significantly longer than the male endurance time in 20% (388.2 ± 53.4 Vs 188.7 ± 16.7 s, P = 0.002), 40% (151.1 ± 14.6 Vs 91.2 ± 4.7 s, P = 0.007), 60% (64.8 ± 5.6 Vs 59.5 ± 1.7 s, P = 0.03) and 80% of MVE (24.7 ± 4.4 Vs 16.5 ± 1.4 s, P = 0.004). The asterisks indicate significant difference between females and males.

In subsequent experiments on much larger number of subjects (108 volunteers), the duration of contraction at a single force of 60% of maximum was used. This was a compromise choice. If smaller forces were used the longer duration of contraction made the experiment unmanageably long. At higher forces there was too little variation in duration between subjects.

In addition, the same volunteers did a similar experiment in which 5 seconds contractions at 60% were alternated with 5 seconds rest periods until volitional exhaustion. Details are shown in table 3.1.1.

The total duration of these intermittent contraction sequences was measured and the data are shown in appendix 1.

Characteristic	Female Mean ± SEM	Male Mean ± SEM	P value t-test
Endurance time sustained (s)	67.1 ± 4.6	54.7 ± 2.5	0.021
Endurance time intermittent (s)	210.5 ± 15.7	167.8 ± 11.8	0.032

Table3.1.2 shows sustained endurance time and endurance time of a series of intermittent contractions. The columns represent the mean ± SEM of the 53 female and 55 male volunteers

EMG median frequency

The surface electromyogram from the belly of the flexor digitorum superficialis (superficial finger flexor) was recorded concurrently during the contractions described previously. Details of the recording technique and the EMG processing are given in detail in chapter 2. In particular the median frequency of the EMG was calculated for the first and last 5 seconds of each sustained contraction. In the case of the intermittent contractions, the median frequency of each 5 seconds of activity was calculated.

In both females and males there was a significant reduction in median frequency ($P < 0.01$). This indicates a strong fatigue state. The reduction in median frequency was similar in both females and males.

The same group of volunteers also participated in the intermittent contraction experiment. This was done after the sustained contractions and after a recovery period of 10 minutes rest.

The initial median frequencies were slightly higher in the later experiment. This suggests that recovery was complete. At volitional exhaustion the median frequency was reduced to 72 (Hz) for females and 68 (Hz) for males. This was substantially higher than the median frequency just before failure in sustained contractions.

Consequently, the differences were much smaller. Interestingly, the reduction in median frequency was significantly greater ($P < 0.01$) in males even though their endurance was less, see appendix 1.

Half relaxation time

The time for half relaxation was assessed for finger flexors of the dominant arm by determining the time taken for the force to fall from 75 to 25% of the maximum value at the end of each 60% MVE in a series of intermittent contractions. The first and last contractions were measured. In both females and males there was a substantial increase in half relaxation time. This indicated a strong fatigue state.

Cardiovascular system

Systolic and diastolic blood pressure were measured in the dominant arm of all volunteers before (at rest) and immediately after both sustained and intermittent contractions. In addition, heart rate was measured in all volunteers simultaneously with blood pressure.

3.2 Comparison of characteristics between females and males in different age groups:

The main aim of this section was to investigate if the muscle fatigue characteristics were different in females and males. To facilitate this the data in each group were divided by sex. Details are shown in table 3.2.1

Group	Age range	Female	Male	Age (female) Mean ± SEM	Age (male) Mean ± SEM
1	5 to 9	5	5	7.6 ± 0.9	7.2 ± 0.8
2	10 to 19	13	13	12.9 ± 0.2	12.6 ± 0.3
3	20 to 29	9	9	22.6 ± 0.7	22.2 ±0.7
4	30 to 39	10	10	33.4 ± 0.7	35.4 ± 0.8
5	40 to 49	10	10	43.2 ± 0.7	44.6 ± 1.1
6	> 50	6	8	52.2 ± 0.7	57.8 ± 1.9

Table 3.2.1 shows the age range and the mean age ± SEM of females and males. The columns represent the 53 female and 55 male volunteers in 6 different age groups.

Statistics

The initial analysis compared pooled data for all male and female volunteers. One-sample Kolmogorov-Smirnov tests confirmed that these data were normally distributed.

The male and female data were compared using a pair T test. A full list of measurement and their changes is shown in appendix 2.

Age groups 1 (5 - 9 years) & 2 (10 – 19 years)

There were no significant differences in any characteristic between females and males in age groups 1 and 2. However, significant differences were found in groups 3 to 6. Since these volunteers are older than 20, this indicates a difference in the adult characteristics. Each adult group will be described in turn.

The data for group 3, ages 20 – 29 years are shown in table 3.2.2.

Age group 3 (20 – 29 years)

In group 3 the males were found to be significantly taller and heavier but there were no significant differences in BMI. The most interesting result in table 3.2.2 is the much greater grip force exerted by males. In group 3 on average male grip force was 37% greater than female grip force. This is more than can be explained by the greater male body weight and height males were 16% heavier and 5.5% taller.

The average systolic blood pressure of females was significantly lower than males before contractions started (P = 0.002). However, after both sustained and intermittent contractions there was no significant difference. There were no significant differences in diastolic pressure. The systolic and diastolic blood pressures and their change before and after contractions are shown in table 3.2.2.

There were no significant differences between the females and males in other characteristics in age group 3.

Characteristic	Female	Male	P value
Height (m)	1.7 ± 0.03	1.8 ± 0.02	0.014
Weight (kg)	62.8 ± 1.7	75.3 ± 3.2	0.004
BMI (kg/m^2)	21.9 ± 0.4	23.7 ± 0.9	0.09
Force related characteristics			
Grip force during MVE (N)	368.3 ± 74.3	584.5 ± 97.5	< 0.0001
Endurance time sustained (s)	67.4 ± 9.2	60.1 ± 3.3	0.512
Endurance time intermittent (s)	176.1 ± 19.9	146.2 ± 11.4	0.212
Initial half relaxation time(s)	0.92 ± 0.008	0.94 ± 0.01	0.416
Final half relaxation time (s)	0.14 ± 0.008	0.16 ± 0.01	0.071
Half relaxation time change(s)	0.05 ± 0.007	0.06 ± 0.01	0.196
EMG related characteristics			
IMF after sustained contraction (Hz)	86.1 ± 3.2	88 ± 6.2	0.783
FMF after sustained contraction (Hz)	38.1 ± 4.1	42.2 ± 3.9	0.476
Frequency change after sustained (Hz)	48 ± 5.3	45.8 ± 4	0.743
IMF after intermittent contractions (Hz)	90.7 ± 3.6	92.1 ± 4.4	0.804
FMF after intermittent contractions (Hz)	76.3 ± 3.5	72.4 ± 3.5	0.449
Frequency change after intermittent (Hz)	14.3 ± 2.5	19.7 ± 2.5	0.151
CVS related characteristics			
Systolic BP before contraction, at rest*	109 ± 2	122 ± 3	0.002
Systolic BP after sustained contraction *	121 ± 4	131 ± 7	0.254
Systolic BP change after sustained *	12 ± 3	9 ± 7	0.658
Systolic BP after intermittent contractions*	122 ± 4	130 ± 7	0.317
Systolic BP change after intermittent *	13 ± 2	8 ± 6	0.456
Diastolic BP before contraction, at rest*	66.3 ± 3	69.9 ± 1.9	0.335
Diastolic BP after sustained contraction*	68.2 ± 3.4	66.2 ± 3.7	0.699
Diastolic BP change after sustained*	1.9 ± 2.8	-3.7 ± 3.7	0.252
Diastolic BP after intermittent contractions*	65.7 ± 3.2	65.8 ± 3.6	0.982
Diastolic BP change after intermittent *	-0.6 ± 3.3	-4.1 ± 2.9	0.447
HR before contractions, at rest ♠	65.6 ± 4.4	62 ± 3.6	0.541
HR after sustained contraction ♠	68.9 ± 5	62.6 ± 4.8	0.379
HR change after sustained contraction♠	3.3 ± 3.1	0.6 ± 2.1	0.463
HR after intermittent contractions ♠	66.4 ± 4.7	63.7 ± 5.5	0.706
HR change after intermittent contractions ♠	0.9 ± 3	1.7 ± 2.7	0.850

Table 3.2.2 shows all characteristics in age group 3 (20 – 29 years). The columns represent the mean ± SEM of the 9 female and 9 male volunteers. The shaded boxes show the significant differences. * mmHg . ♠ bpm.

Age group 4 (30 – 39 years)

In age group 4 the males were found to be significantly taller and heavier. Details are shown in table 3.2.3. There were no significant differences in BMI.

As described earlier for group 3, the males had a significantly greater MVE, and they were heavier and taller.

There were no significant differences between the females and males in other characteristics in age group 4.

Characteristic	Female	Male	P value
Height (m)	1.66 ± 0.02	1.76 ± 0.02	0.001
Weight (kg)	62.6 ± 1.7	80.4 ± 3.2	0.007
BMI (kg/m^2)	22.7 ± 0.8	25.9 ± 1.4	0.065
Force related characteristics			
Grip force during MVE (N)	308.5 ± 74.3	527.8 ± 87	< 0.0001
Endurance time sustained (s)	67.6 ± 6	58.3 ± 5	0.265
Endurance time intermittent (s)	215.8 ± 33.6	163.6 ± 15	0.174
Initial half relaxation time(s)	0.09 ± 0.01	0.08 ± 0.01	0.548
Final half relaxation time (s)	0.14 ± 0.02	0.13 ± 0.01	0.358
Half relaxation time change(s)	0.04 ± 0.007	0.05 ± 0.007	0.445
EMG related characteristics			
IMF after sustained contraction (Hz)	83.4 ± 4.9	78.8 ± 4.4	0.494
FMF after sustained contraction (Hz)	43.7 ± 7.3	40.9 ± 6.3	0.775
Frequency change after sustained (Hz)	39.6 ± 3.4	37.8 ± 3.9	0.730
IMF after intermittent contractions (Hz)	89.1 ± 5.2	79.7 ± 6.1	0.263
FMF after intermittent contractions (Hz)	67.8 ± 6	52.7 ± 6.6	0.106
Frequency change after intermittent (Hz)	21.2 ± 4.7	27 ± 5.1	0.411
CVS related characteristics			
Systolic BP before contraction, at rest*	109.4 ± 3.9	118.5 ± 4.1	0.126
Systolic BP after sustained contraction *	121.8 ± 3.6	123.8 ± 3.6	0.696
Systolic BP change after sustained *	12.4 ± 3.2	5.3 ± 2.1	0.080
Systolic BP after intermittent contractions*	124.1 ± 4.9	123.8 ± 3.6	0.961
Systolic BP change after intermittent *	14.7 ± 3.9	5.3 ± 4.9	0.150
Diastolic BP before contraction, at rest*	74.8 ± 1.1	73.2 ± 2.4	0.545
Diastolic BP after sustained contraction*	76.1 ± 2.5	72.9 ± 2.4	0.364
Diastolic BP change after sustained*	1.3 ± 2.2	-0.3 ± 2.4	0.625
Diastolic BP after intermittent contractions*	71.4 ± 2.5	73.6 ± 2.3	0.526
Diastolic BP change after intermittent *	-3.4 ± 1.9	0.4 ± 2.3	0.228
HR before contractions, at rest ♠	72.5 ± 4.3	70.2 ± 3.8	0.692
HR after sustained contraction ♠	70.9 ± 5.5	71.9 ± 4.1	0.885
HR change after sustained contraction♠	-1.6 ± 2	1.7 ± 2.1	0.278
HR after intermittent contractions ♠	73.8 ± 5	74.4 ± 5	0.889
HR change after intermittent contractions ♠	1.3 ± 2.6	4.6 ± 3.1	0.427

Table 3.2.3 shows all characteristics in age group 4 (30 – 39 years). The columns represent the mean ± SEM of the 10 female and 10 male volunteers. The shaded boxes show the significant differences. * mmHg . ♠ bpm.

Age group 5 (40 – 49 years)

In age group 5 the males were found to be significantly taller and heavier. There were no significant differences in BMI. These data are in table 3.2.4. As before the males had a much greater grip force. On average male grip force was 44% greater than female grip force.

During sustained contractions, the mean median frequency of group 5 volunteers was not significantly different between females and males.

The same group of volunteers also participated in the intermittent contraction experiment. However, the females mean median frequency change after a series of intermittent contractions was significantly different from the males.

There were no significant differences between the females and males in other characteristics in age group 5.

Characteristic	Female	Male	P value
Height (m)	1.62 ± 0.02	1.79 ± 0.03	< 0.0001
Weight (kg)	66.6 ± 3.7	85.9 ± 4.8	0.005
BMI (kg/m^2)	25.3 ± 1.3	26.6 ± 1.2	0.473
Force related characteristics			
Grip force during MVE (N)	293.6 ± 66	525.8 ± 80.8	< 0.0001
Endurance time sustained (s)	74.9 ± 18.7	60.3 ± 3.9	0.176
Endurance time intermittent (s)	293 ± 42.6	198.5 ± 48.6	0.161
Initial half relaxation time(s)	0.12 ± 0.02	0.09 ± 0.01	0.054
Final half relaxation time (s)	0.16 ± 0.02	0.14 ± 0.01	0.216
Half relaxation time change(s)	0.04 ± 0.005	0.04 ± 0.008	0.481
EMG related characteristics			
IMF after sustained contraction (Hz)	82.4 ± 5.7	78.8 ± 5	0.645
FMF after sustained contraction (Hz)	55.6 ± 7.6	39.4 ± 6.3	0.119
Frequency change after sustained (Hz)	26.2 ± 4.2	39.4 ± 5.4	0.077
IMF after intermittent contractions (Hz)	87.6 ± 4.3	82.8 ± 5.5	0.421
FMF after intermittent contractions (Hz)	74.8 ± 5.1	59.6 ± 5.9	0.066
Frequency change after intermittent (Hz)	13.8 ± 3.1	23.2 ± 2.2	0.023
CVS related characteristics			
Systolic BP before contraction, at rest*	119.5 ± 3.7	124.7 ± 4.1	0.359
Systolic BP after sustained contraction *	134.5 ± 3.8	137.1 ± 4.4	0.662
Systolic BP change after sustained *	15 ± 4.3	12.4 ± 2.9	0.624
Systolic BP after intermittent contractions*	128.9 ± 4.5	139.6 ± 5.5	0.148
Systolic BP change after intermittent *	9.4 ± 3.8	14.9 ± 5.2	0.405
Diastolic BP before contraction, at rest*	79.1 ± 2.3	80.1 ± 2.7	0.759
Diastolic BP after sustained contraction*	76.6 ± 4.1	78.9 ± 2.5	0.637
Diastolic BP change after sustained*	-2.5 ± 4.1	-1.2 ± 1.8	0.774
Diastolic BP after intermittent contractions*	78.6 ± 3.6	82.6 ± 2.6	0.386
Diastolic BP change after intermittent *	-0.5 ± 3.6	2.5 ± 2.1	0.478
HR before contractions, at rest ♠	74.9 ± 2.8	70.6 ± 2.9	0.298
HR after sustained contraction ♠	72.3 ± 3.3	70.2 ± 3.7	0.680
HR change after sustained contraction♠	-2.6 ± 2.5	-0.4 ± 2.2	0.515
HR after intermittent contractions ♠	72.3 ± 3.3	68.1 ± 3.3	0.383
HR change after intermittent contractions ♠	-2.6 ± 2.45	-2.5 ± 1.9	0.975

Table 3.2.4 shows all characteristics in age group 5 (40 – 49 years). The columns represent the mean ± SEM of the 10 females and 10 males volunteers. The shaded boxes show the significant differences. * mmHg . ♠ bpm.

Age group 6 (+ 50 years)

In age group 6 the males were found to be significantly taller and heavier. There were no significant differences in BMI. Again, the males had a greater grip force. On average male grip force was 47% greater than female grip force. Data are shown in table 3.2.5.

There were no significant differences between the females and males in other characteristics in age group 6.

Characteristic	Female	Male	P value
Height (m)	1.64 ± 0.03	1.82 ± 0.03	< 0.0001
Weight (kg)	60 ± 6	86.1 ± 4.5	0.004
BMI (kg/m^2)	22.2 ± 1.8	26± 0.8	0.064
Force related characteristics			
Grip force during MVE (N)	274.6 ± 53.3	519 ± 107.6	< 0.0001
Endurance time sustained (s)	82 ± 12.2	56.4 ± 6.6	0.072
Endurance time intermittent (s)	301.7 ± 61	180 ± 18.5	0.052
Initial half relaxation time(s)	0.07 ± 0.01	0.11 ± 0.02	0.220
Final half relaxation time (s)	0.12 ± 0.02	0.16 ± 0.02	0.595
Half relaxation time change(s)	0.04 ± 0.01	0.05 ± 0.01	0.649
EMG related characteristics			
IMF after sustained contraction (Hz)	86.8 ± 6.7	89 ± 7.6	0.841
FMF after sustained contraction (Hz)	49.5 ± 11.4	49.2 ± 6.8	0.981
Frequency change after sustained (Hz)	37.3 ± 8.3	39.7 ± 7.5	0.834
IMF after intermittent contractions (Hz)	94.8 ± 6.8	94.2 ± 7.3	0.956
FMF after intermittent contractions (Hz)	81.4 ± 5.5	72.9 ± 8.1	0.436
Frequency change after intermittent (Hz)	13.4 ± 3.6	21.2 ± 3.2	0.136
CVS related characteristics			
Systolic BP before contraction, at rest*	126.5 ± 9.6	133.6 ± 6	0.523
Systolic BP after sustained contraction *	140 ± 8.5	149.1 ± 8.1	0.461
Systolic BP change after sustained *	13.5 ± 5.1	15.5 ± 2.8	0.717
Systolic BP after intermittent contractions*	141.5 ± 12.2	151 ± 8.7	0.525
Systolic BP change after intermittent *	15 ± 4.7	17.4 ± 5.1	0.748
Diastolic BP before contraction, at rest*	86.3 ± 4.6	75.7 ± 4.1	0.127
Diastolic BP after sustained contraction*	90 ± 5.7	79 ± 4.2	0.140
Diastolic BP change after sustained*	3.7 ± 1.8	3.2 ± 1.5	0.860
Diastolic BP after intermittent contractions*	86.3 ± 6.9	89.6 ± 6.1	0.728
Diastolic BP change after intermittent *	0 ± 3	13.9 ± 7.7	0.165
HR before contractions, at rest ♠	79.8 ± 6.5	68 ± 7.3	0.267
HR after sustained contraction ♠	76.7 ± 7.2	70.4 ± 6.6	0.537
HR change after sustained contraction♠	-3.2 ± 2.6	2.4 ± 1.5	0.073
HR after intermittent contractions ♠	80.2 ± 6.9	69.6 ± 6.9	0.314
HR change after intermittent contractions ♠	0.3 ± 1.1	1.6 ± 1.6	0.545

Table 3.2.5 shows all characteristics in age group 6 (+ 50 years). The columns represent the mean ± SEM of the 6 females and 8 males volunteers. The shaded boxes show the significant differences. * mmHg . ♠ bpm.

3.3 Comparison of characteristics between age groups:

The main aim of this section was to investigate age related changes. The analysis compares pooled data for each age group of volunteers. To facilitate this the data were divided into 6 age groups. Groups contain male and female volunteers. Details are shown in table 3.3.1. It can be seen that the height increases progressively in group 1, 2, and 3. The weight increases with age until the age of 50 years.

Group	Age range	Number of volunteers	Age Mean ± SEM (year)	Height Mean ± SEM (m)	Weight Mean ± SEM (Kg)
1	5 to 9	10	7.4 ± 0.6	1.3±0.03	29 ± 2.7
2	10 to 19	26	12.7 ± 0.2	1.6±0.02	48 ± 2
3	20 to 29	18	22.4 ± 0.5	1.7±0.02	69 ± 2.3
4	30 to 39	20	34.4 ± 0.6	1.7±0.02	71 ± 3.5
5	40 to 49	20	43.9 ± 0.6	1.7±0.02	76 ± 3.7
6	> 50	14	55.4 ± 1.3	1.7±0.03	75 ± 5

Table 3.3.1 shows the age range and the mean age, height and weight ± SEM of females and males in different age groups. The number of volunteers is shown in each age group.

Statistics

One-sample Kolmogorov-Smirnov tests confirmed that these data were normally distributed. The data for age groups were compared using one way analysis of variance. There were significant differences between age groups in some characteristics. Tukey's HSD follow up test was used. A full list of measurements and their changes with age is shown in appendix 3.

Some age related changes were clearly significant. For example the mean grip force illustrated in figure 3.3.1 shows progressive rise through groups 1, 2 and 3. The grip force then shows no significant change with age.

Force

The mean of the maximum voluntary grip was calculated for each age group. The lowest maximum voluntary grip was group 1 and the highest maximum voluntary grip was seen in group 3. There were significant differences between mean maximum voluntary grip in group 1 compared to groups 3, 4, 5 and 6 (P values <0.0001). In addition the mean MVE in group 2 was significantly different from groups 3, 4, 5 and 6 (P values < 0.0001). There was no significant difference between group 1 and 2 in terms of mean MVE. Details are shown in table 3.3.2 and figure 3.3.1.

Endurance time

The endurance time of sustained contractions was measured and the mean was calculated for different age groups. There were no significant differences in endurance time between the age groups. There was a clear trend for longer endurance times in groups 3-6, than in 1 and 2. However, the spread of data made it difficult to identify a statistically significant result. Details are shown in table 3.3.2.

The intermittent endurance time was measured in all 6 groups. The results show that as age increases, the endurance time of contractions increases. The endurance time in group 1 was significantly shorter than group 5 (P = 0.029). There was no significant different between other age groups. However, again there was a clear trend for the times to increase until group 5. Once more the spread in data was large. Details are shown in table 3.3.2.

Group	MVE (N) Mean ± SEM	Sustained endurance (s) Mean ± SEM	Intermittent endurance (s) Mean ± SEM	N*
1	138 ± 18	44.2 ± 4.2	128 ± 9.7	10
2	243 ± 16	50.5 ± 5.4	163.3 ±17.2	26
3	476 ± 31	64.2 ± 4.8	161.2 ± 11.7	18
4	418 ± 28	62.9 ± 4.1	189.7 ±18.9	20
5	410 ± 29	67.6 ± 9.5	245.7 ± 33.3	20
6	414 ± 39	67.4 ± 7.1	232.1 ± 31.6	14

Table 3.3.2 shows the MVE, endurance time of sustained contraction and endurance time of a series of intermittent contractions in 6 different age groups. The columns represent the mean ± SEM of the female and male volunteers. * Number of volunteers.

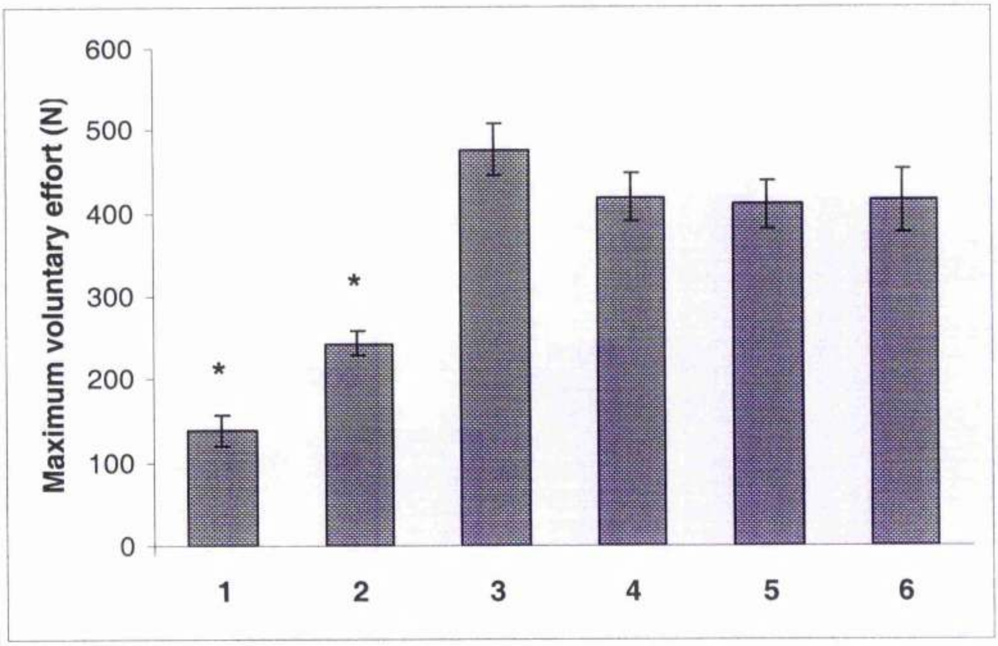


Figure 3.3.1shows the MVE in the finger flexor muscles of the dominant arm. The columns represent the mean ± SEM of each group (female and male) volunteers. The mean MVE in group 1 was significantly different from groups 3 to 6 ($P < 0.0001$). In addition the mean MVE in group 2 was significantly different from mean MVE in groups 3 to 6 ($p < 0.0001$). There was no significant difference between the mean MVE in other groups.

The asterisk indicates the significant difference between groups ($P<0.01$).

a) Sustained contraction

The endurance time of sustained contractions was measured and the mean ± SEM was calculated for different age groups. Details are shown in table 3.3.2 and illustrated in figure 3.3.2. The shortest endurance time was seen in group 1 and the longest time was in group 5. There were no significant differences between the age groups.

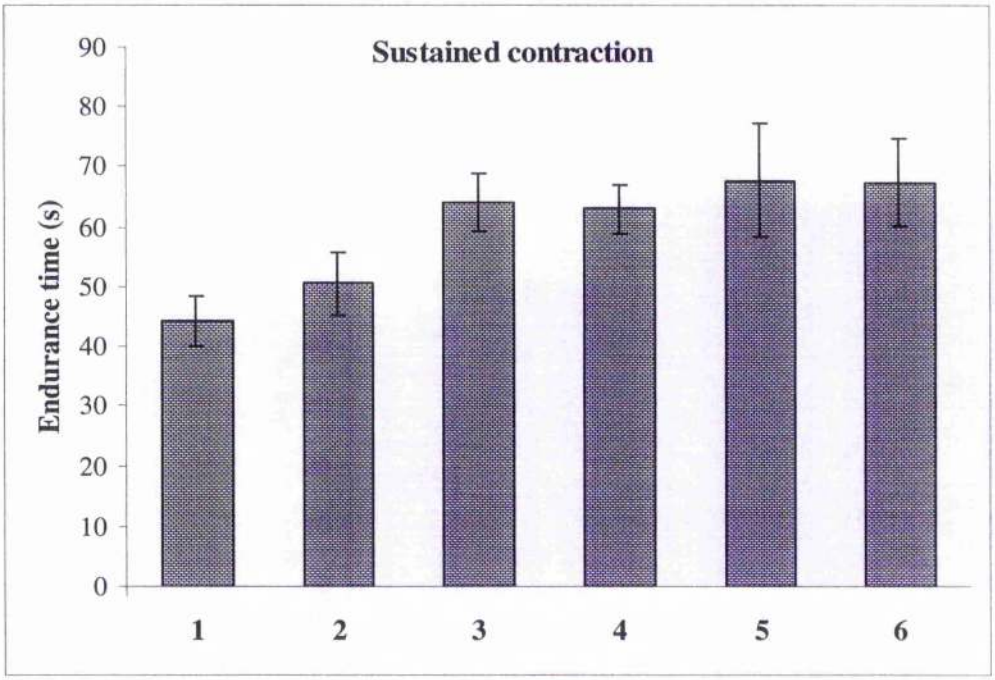


Figure 3.3.2 shows the endurance time in sustained contraction of flexor muscles of the dominant arm. The columns represent the mean ± SEM of each group (female and male) volunteers. There were no significant differences between the mean endurance time in six age groups.

b) Intermittent contractions

The endurance time of intermittent contractions was measured in all 6 groups. Details are shown in table 3.3.2 and illustrated in figure 3.3.3. The results show a trend for the endurance times to be longer in the older groups. The endurance time in group 1 was significantly shorter than group 5, There was no significant difference between other age groups.

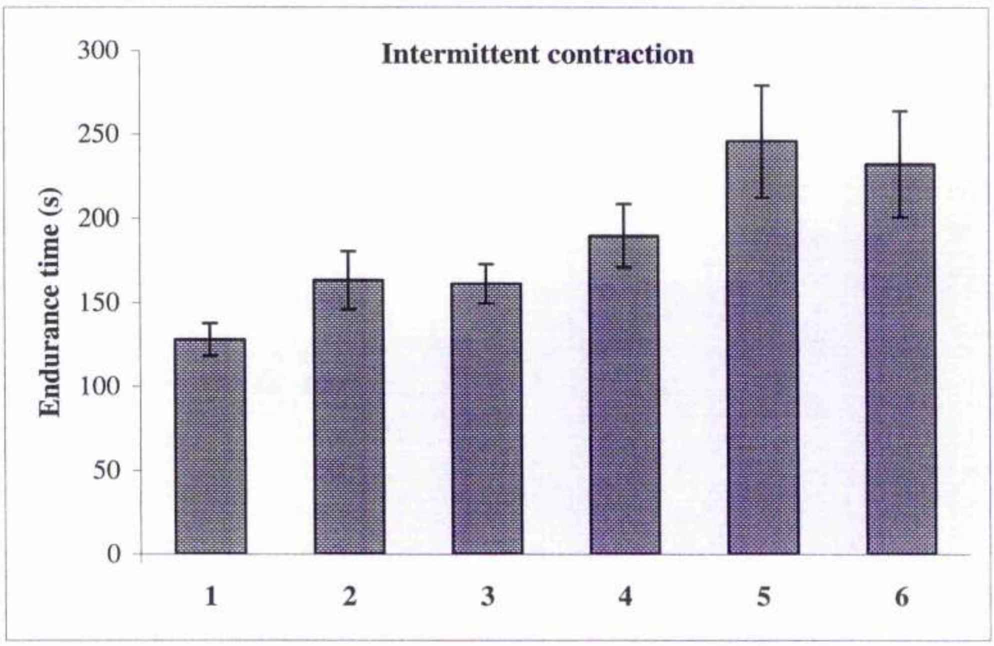


Figure 3.3.3 shows the endurance time of a series of intermittent contractions of flexor muscles of the dominant arm. The columns represent the mean ± SEM of each group (female and male) volunteers. The endurance time in group 1 was significantly shorter than group 5. There was no significant different between other age groups.

EMG median frequency

The surface electromyogram from the belly of the flexor digitorum superficialis was recorded concurrently during the contractions described previously. Details of the recording technique and the EMG processing are given in detail in chapter 2. In particular the median frequency of the EMG was calculated for the first and last 5 seconds of each sustained contraction. In the case of the intermittent contractions, the median frequency of each 5 seconds of activity was calculated. The values are shown in table 3.3.3 and 3.3.4.

During sustained contractions, the mean median frequency of the age group volunteers was not significantly different in the initial 5 seconds period. Neither were the median frequencies different in age groups at the end of the contraction.

The same group of volunteers also participated in the intermittent contraction experiment. This was carried out after the sustained contractions and after a recovery period of 10 minutes rest. The recovery of the EMG was complete after 10 minutes rest. The initial median EMG frequencies are not significantly different at the beginning of both tests ($P > 0.05$) for details see appendix 3. This can be seen by inspecting the initial values in table 3.3.3 and 3.3.4. During intermittent contractions, the mean median frequency of the age groups volunteers was not significantly different in the initial 5 seconds period. Neither were the median frequencies different in age groups at the end of the contraction.

Median Frequencies						
	Group 1 Mean ± SEM	Group 2 Mean ± SEM	Group 3 Mean ± SEM	Group 4 Mean ± SEM	Group 5 Mean ± SEM	Group 6 Mean ± SEM
First 5 seconds sustained	83.1±3.6 (Hz)	90.4±3.3 (Hz)	87±3.4 (Hz)	81.1±3.2 (Hz)	80.6±3.7 (Hz)	88±5 (Hz)
Last 5 seconds sustained	59±3.5 (Hz)	56.9±4.4 (Hz)	40±2.8 (Hz)	42.3±4.8 (Hz)	47.5±5.1 (Hz)	49.3±6 (Hz)
Difference	24.1±5	33.5±3	46.9±3.2	38.8±2.5	32.9±3.7	38.7±5.4
N*	10	26	18	20	20	14

Table 3.3.3 shows the value of mean median frequency of sustained contraction in different age groups (females and males). The columns represent the mean ± SEM of the female and male volunteers. * Number of volunteers

In all age groups there was a significant reduction in median frequency. The P values were less than 0.0001. This indicates a strong fatigue state.

The median frequencies of the first and last intermittent contractions are shown in table 3.3.4.

Median Frequencies						
	Group 1 Mean ± SEM	Group 2 Mean ± SEM	Group 3 Mean ± SEM	Group 4 Mean ± SEM	Group 5 Mean ± SEM	Group 6 Mean ± SEM
First 5 seconds intermittent	85.7±3 (Hz)	91.4±3.8 (Hz)	91.4±2.8 (Hz)	84.4±4.1 (Hz)	85.7±3.5 (Hz)	94.5±4.9 (Hz)
Last 5 seconds intermittent	69.1±4.2 (Hz)	72.6±4.3 (Hz)	74.4±2.5 (Hz)	60.3±4.7 (Hz)	67.2±4.2 (Hz)	76.6±5.1 (Hz)
Difference	16.6±2.5	18.8±2.1	17±1.8	24.1±3.5	18.5±2.1	17.9±2.6
*N	10	26	18	20	20	14

Table 3.3.4 shows the mean median frequencies of the first and last contractions and their difference of a series of intermittent contractions in different age groups (female and male). The columns represent the mean ± SEM of the female and male volunteers. The initial median frequencies were slightly higher in this experiment. This suggests that recovery was complete. *N number of volunteers.

The difference in median frequency during the series of intermittent contractions is substantially less than that doing the sustained contraction. The P values were ≤ 0.001 except in group 1, even though both failure of voluntary contraction happened in both cases. Details illustrated in figure 3.3.4.

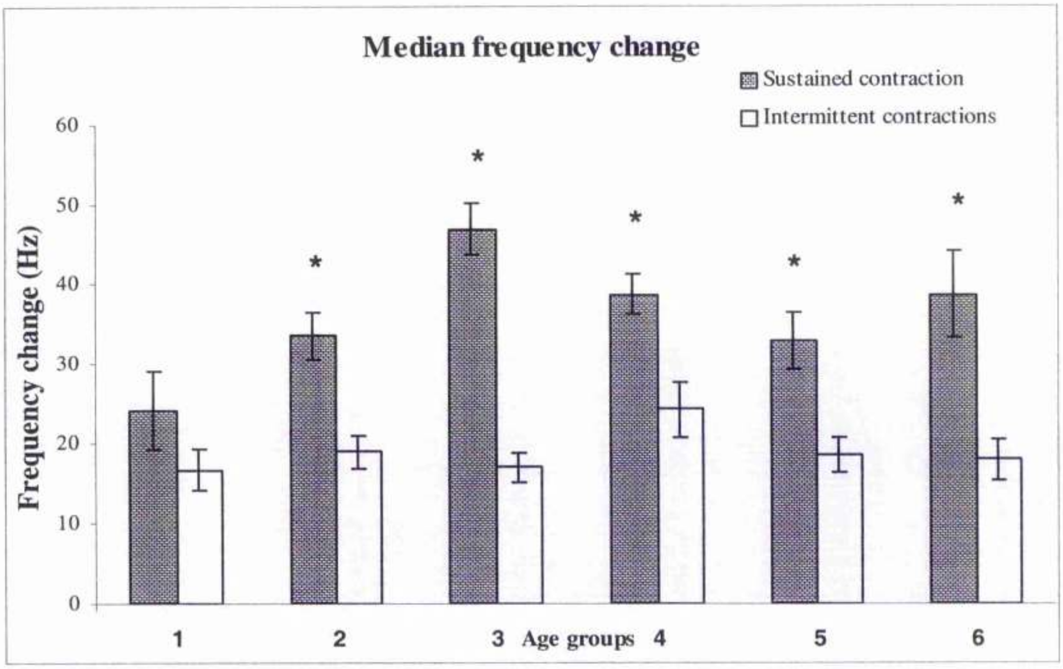


Figure 3.3.4 shows the EMG median frequency change of the dominant arm after sustained contraction and after a series of intermittent contractions. The columns represent the mean ± SEM of each group (female and male) volunteers. The mean median frequency change after sustained contraction in group 2 ($P \leq 0.0002$), group 3 ($P \leq 0.0001$), group 4 ($P = 0.001$), group 5 ($P = 0.001$) and group 6 ($P = 0.001$) were significantly different the from mean median frequency change after a series of intermittent contractions in the same age groups. There were no significant differences between the mean median frequency change after sustained contraction and the mean median frequency change after intermittent contractions in group 1 ($P = 0.194$). The asterisks indicate the significant difference between groups ($P<0.01$).

Half relaxation time

The time for half relaxation was assessed for finger flexors of the dominant arm by determining the time taken for the force to fall from 75 to 25% of the maximum value at the end each 60% MVE in a series of intermittent contractions. The first and last contractions were measured. The half relaxation time of the first and last and the difference are shown in table 3.3.5. In all age groups there was a substantial increase in half relaxation time P >0.001. This indicated a strong fatigue state. An ANOVA was used to test these data. No significant differences were found between the time for the first contractions in all groups. Similarly, there was no difference between the final times. The results of the ANOVA test can be found on appendix 3

Half relaxation time						
Intermittent contractions	Group 1 Mean ± SEM	Group 2 Mean ± SEM	Group 3 Mean ± SEM	Group 4 Mean ± SEM	Group 5 Mean ± SEM	Group 6 Mean ± SEM
First contraction	91.5 ± 10 (ms)	84.1±5.5 (ms)	93.6±7.1 (ms)	88.4±11 (ms)	109±11 (ms)	96±13 (ms)
Last contraction	140.6±15 (ms)	123.1±6 (ms)	153.5±8 (ms)	137.2±14 (ms)	150.4±13 (ms)	145±18 (ms)
Difference	49.1±8	39±5	60±6	48.7±5	40.6±4	49±8
N*	10	26	18	20	20	14

Table 3.3.5 shows the half relaxation time of the first and last contractions and their difference of a series of a series of intermittent contractions in different age groups (female and male). The columns represent the mean ± SEM of the female and male volunteers.

* Number of volunteers

Cardiovascular system

Blood pressure

Systolic and diastolic blood pressures were measured in the dominant arm of all volunteers before (at rest) and immediately after both sustained and intermittent contractions. In addition, heart rate was measured in all volunteers at the same time as blood pressure.

The mean systolic and diastolic blood pressure before contractions and after both sustained and intermittent contractions show a progressive increase with age. The average of systolic blood pressure before contractions was significantly lower than the average blood pressure after sustained and a series of intermittent contractions ($P < 0.0001$). This is illustrated in figures 3.3.5 and 3.3.6. These changes are what might be expected.

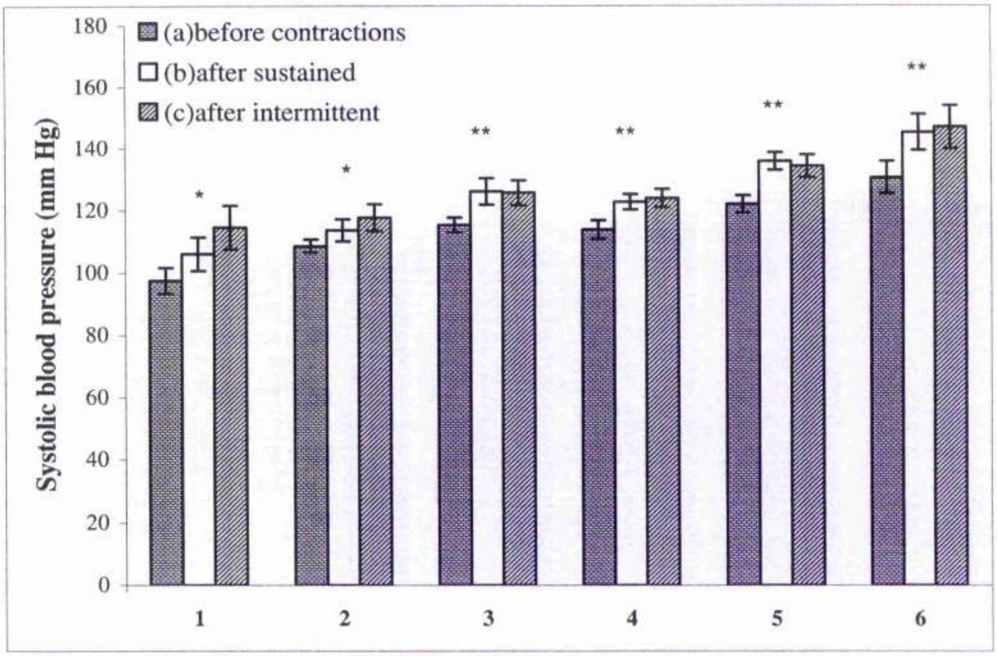


Figure 3.3.5 shows the systolic blood pressure of the dominant arm before contractions (**a**), after sustained contraction (**b**) and after intermittent contractions (**c**). The columns represent the mean ± SEM of each group (female and male) volunteers. (**a**) The mean systolic blood pressure in group 1 was significantly different from the groups 3 to 6 ($P \leq 0.01$). In addition the mean systolic blood pressure in group 2 was significantly different from mean systolic blood pressure in groups 5 and 6 ($p \leq 0.01$). The mean systolic blood pressure in group 3 was significantly different from mean systolic blood pressure in group 6 ($p = 0.018$). In addition, the mean systolic blood pressure in group 4 was significantly different from mean systolic blood pressure in groups 6 ($p = 0.005$). There were no significant differences between the mean systolic blood pressure in other groups.

(**b**) The mean systolic blood pressure after sustained contraction in group 1 was significantly different from groups 3 to 6 ($P \leq 0.03$). In addition the mean systolic blood pressure in group 2 was significantly different from mean systolic blood pressure in groups 5 and 6 ($p < 0.0001$). The mean systolic blood pressure in group 3 was significantly different from mean systolic blood pressure in group 6 ($p = 0.018$). In addition the mean systolic blood pressure in group 4 was significantly different from mean systolic blood pressure in group 6 ($p = 0.002$). There were no significant differences between the mean systolic blood pressure in other groups.

(**c**) The mean systolic blood pressure after intermittent contractions in group 1 was significantly different from the group 6 ($P = 0.002$). In addition, the mean systolic blood pressure in group 2 was significantly different from mean systolic blood pressure in group 6 ($p < 0.0001$). The mean systolic blood pressure in group 3 was significantly different from mean systolic blood pressure in group 6 ($p = 0.033$). In addition, the mean systolic blood pressure in group 4 was significantly different from mean systolic blood pressure in group 6 ($p = 0.013$). There were no significant differences between the mean systolic blood pressure in other groups. In additions, there were no significant differences between the mean systolic blood pressure change in six groups after both sustained and intermittent contractions. Asterisks show significant difference between BP at rest and after contractions in each group. * $P < 0.05$ and ** $P < 0.001$.

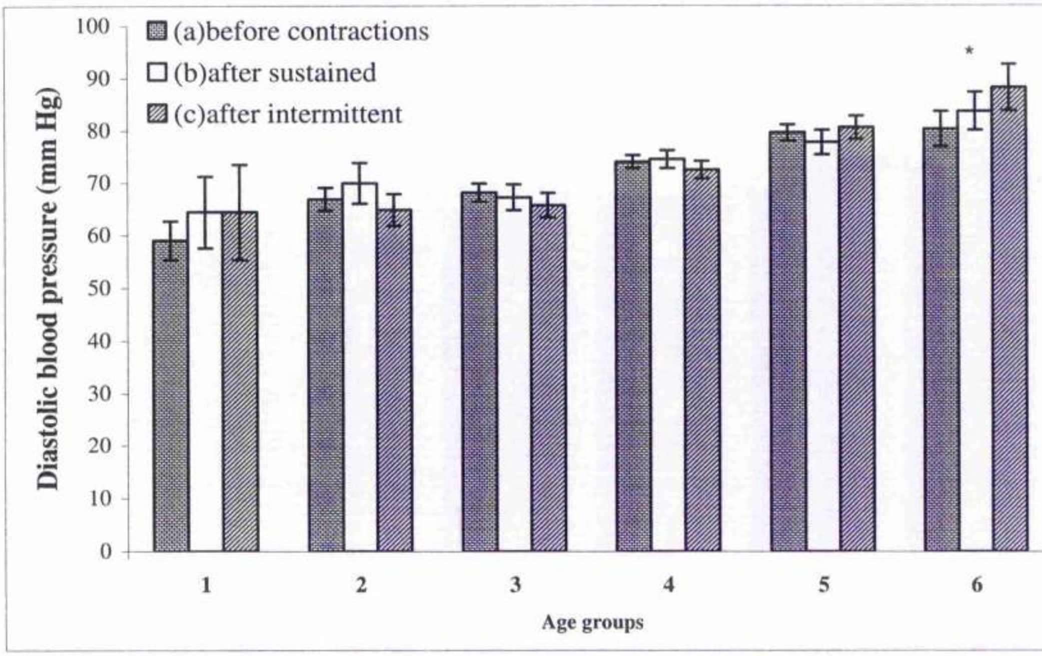


Figure 3.3.6 shows the diastolic blood pressure of the dominant arm before contractions (**a**), after sustained contraction (**b**) and after intermittent contractions (**c**). The columns represent the mean ± SEM of each group (female and male) volunteers. The mean diastolic blood pressure in group 1 was significantly different from the groups 4 to 6 ($P \leq 0.001$). In addition the mean diastolic blood pressure in group 2 was significantly different from mean diastolic blood pressure in groups 5 and 6 ($P \leq 0.001$). The mean diastolic blood pressure in group 3 was significantly different from mean diastolic blood pressure in groups 5 and 6 ($P \leq 0.005$). There were no significant differences between the mean diastolic blood pressure in other groups.

(**b**) The mean diastolic blood pressure after sustained contraction in group 1 was significantly different from the group 6 ($P = 0.021$). In addition the mean diastolic blood pressure in group 3 was significantly different from mean diastolic blood pressure in group 6 ($P = 0.023$). There were no significant differences between the mean diastolic blood pressure after sustained contraction in other groups. (**c**) The mean diastolic blood pressure after intermittent contractions in group 1 was significantly different from the group 6 ($P = 0.002$). In addition, the mean diastolic blood pressure in group 2 was significantly different from mean diastolic blood pressure in groups 6 ($p < 0.0001$). The mean diastolic blood pressure in group 3 was significantly different from mean diastolic blood pressure in group 5 and 6 ($p = 0.026$ and $p < 0.0001$). In addition, the mean diastolic blood pressure in group 4 was significantly different from mean systolic blood pressure in group 6 ($p = 0.030$). There were no significant differences between the mean diastolic blood pressure in other groups. In addition, there were no significant differences between the mean diastolic blood pressure change in six groups after both sustained and intermittent contractions. Asterisk shows significant difference between BP at rest and after contractions in each group. * P < 0.05.1.

A full list of measurements and their changes is shown in appendix 3.

Heart rate

In addition to systolic and diastolic blood pressure heart rate was measured in the dominant arm of all volunteers before (at rest) and immediately after both sustained and intermittent contractions in all volunteers at the same time as blood pressure.

There was significant difference between mean heart rate in group 1and group 3 before contractions (P = 0.012). In addition the mean heart rate after sustained contraction in group 1 was significantly faster than all other groups (P ≤ 0.045). Mean heart rate after intermittent contractions in group 3 was significantly slower than group1 (P = 0.005) and group 2 (P = 0.036). There were no significant differences between the mean heart rate in other groups. Details are shown in below (table 3.3.6).

Heart rate (bpm)						
	Group 1 Mean ± SEM	Group 2 Mean ± SEM	Group 3 Mean ± SEM	Group 4 Mean ± SEM	Group 5 Mean ± SEM	Group 6 Mean ± SEM
Before contractions	81.4±4.7 (bpm)	72.8±2.5 (bpm)	63.8±2.8 (bpm)	71.3±2.8 (bpm)	72.7±2 (bpm)	73.1±5.1 (bpm)
After sustained	90.5±4.4 (bpm)	71.5±2.7 (bpm)	65.7±3.5 (bpm)	71.4±3.3 (bpm)	71.2±2.4 (bpm)	73.1±4.8 (bpm)
After intermittent	85.6±4.8 (bpm)	78.3±2.4 (bpm)	65.1±3.5 (bpm)	74.3±3.4 (bpm)	70.2±2.3 (bpm)	74.1±5 (bpm)
N*	10	26	18	20	20	14

Table 3.3.6 shows the mean heart rate before contractions (at rest), immediately after the sustained and intermittent contractions in different age groups (female and males). The columns represent the mean ± SEM of the female and male volunteers. There was no significant different within age groups * Number of volunteers.

3.4 Comparison of fatigue characteristics between different age groups in female volunteers:

The main aim of this section was to investigate age related changes in females.

The analysis compares data for each age group of female volunteers. To facilitate this the data were divided into 6 age groups. Details are shown in table 3.4.1. It can be seen that the height increases progressively in group 1, 2, and 3. The weight increases with age until the age of 50 years.

Group	Age range	Number of volunteers	Age Mean ± SEM (year)	Height Mean ± SEM (m)	Weight Mean ± SEM (Kg)
1	5 to 9	5	7.6 ± 0.9	1.31±0.05	33 ± 2
2	10 to 19	13	12.8 ± 0.2	1.55±0.03	48 ± 2.9
3	20 to 29	9	22.6 ± 0.7	1.69±0.03	62 ± 1.7
4	30 to 39	10	33.4 ± 0.7	1.66±0.02	62 ± 3
5	40 to 49	10	43.2 ± 0.6	1.62±0.02	66 ± 3.7
6	> 50	6	52.2 ± 0.7	1.64±0.03	60±6

Table 3.4.1 shows the age range and the mean age, height and weight ± SEM of females in different age groups. The number of volunteers is shown in each age group.

Statistics

The data for age groups were compared using one-way analysis of variance. Tukey's HSD follow up test was used. A full list of measurements and their changes is shown in appendix 4.

Some age related changes were clearly significant. For example the mean grip force illustrated in figure 3.4.1 shows a progressive rise through groups 1, 2 and 3. The grip force then shows no significant change with age.

The mean of the maximum voluntary grip force was calculated for each age group. The lowest maximum voluntary grip was group 1 and the highest maximum voluntary grip was observed in group 3. There were significant differences between mean maximum voluntary grip in group 1 with groups 3, 4, 5 and 6 (P values < 0.016). In addition the mean MVE in group 2 was significantly different from group 3

(P values < 0.0001). There was no significant difference between group 1 and 2 in terms of mean MVE. Details are shown in table 3.4.2 and figure 3.4.1.

Group	MVE (N) Mean ± SEM	Sustained endurance (s) Mean ± SEM	Intermittent endurance (s) Mean ± SEM	N*
1	136 ± 32	44.6 ± 3.9	125 ± 14.1	5
2	232 ± 16	54.6 ± 8.1	157.7 ± 20.5	13
3	368 ± 23	67.4 ± 9.2	176.1 ± 19.9	9
4	308 ± 18	67.6 ± 6.2	215.8 ± 33.6	10
5	293 ± 17	74.9 ± 18.7	293 ± 42.7	10
6	274 ± 20	82 ± 12.2	301.7 ± 61	6

Table 3.4.2 shows the MVE, endurance time of sustained contraction and endurance time of a series of intermittent contractions in 6 different age groups. The columns represent the mean ± SEM of the female volunteers. * Number of volunteers.

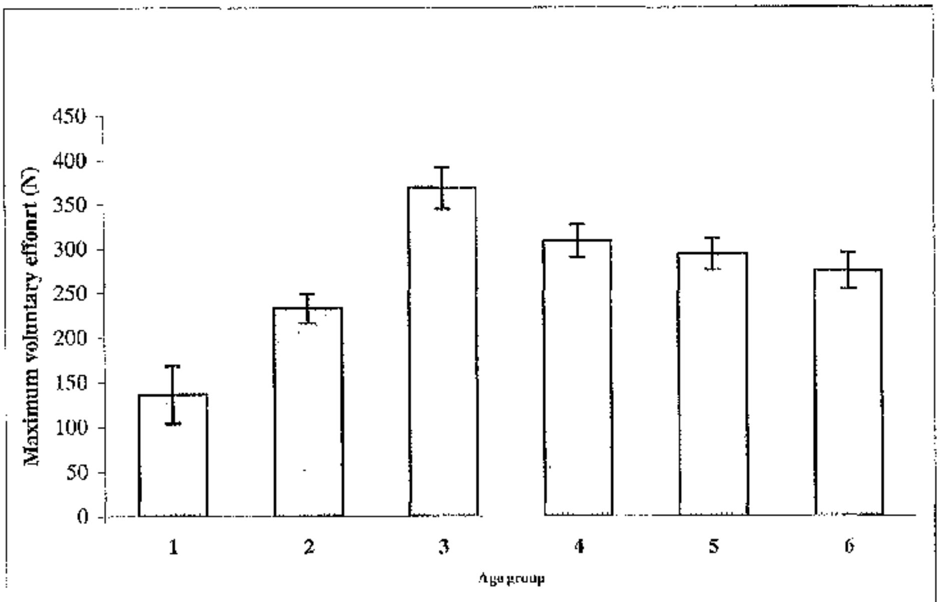


Figure 3.4.1 shows the maximum voluntary grip force in the finger flexor muscles of the dominant arm. The columns represent the mean ± SEM of each group female volunteers. The mean MVE in group 1 was significantly different from the groups 3 to 6 ($P < 0.016$). In addition the mean MVE in group 2 was significantly different from mean MVE in group 3 ($p < 0.0001$). There were no significant differences between the mean MVE in other groups.

Endurance time

a) Sustained contraction

The endurance time of sustained contractions was measured and the mean ± SEM was calculated for different age groups. Details are shown in table 3.4.2 and illustrated in figure 3.4.2. The shortest endurance times were seen in group 1 and the longest times were in group 5. There were no significant differences between the age groups. There was a clear trend for longer endurance times in groups 3-6, than in 1 and 2. However, the large standard deviations made it difficult to identify a statistically significant result. Details are shown in table 3.4.2.

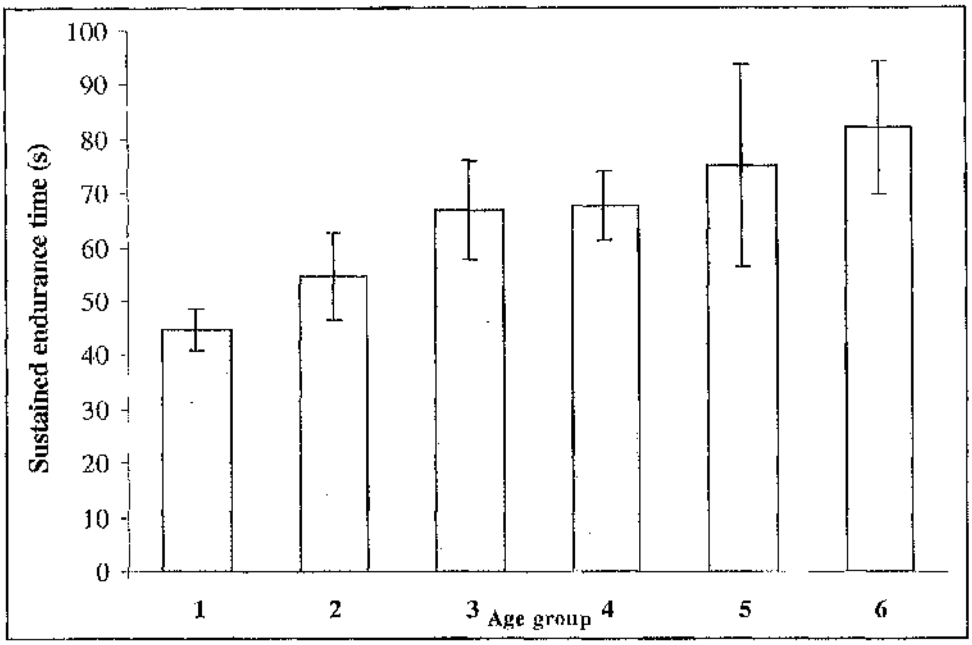


Figure 3.4.2 shows the endurance times of sustained contractions of flexor muscles of the dominant arm. The columns represent the mean ± SEM of each female group volunteers. There were no significant differences between the mean endurance time in six age groups.

b) Intermittent contractions

The endurance time of intermittent contractions was measured in all 6 groups. Details are shown in table 3.4.2 and illustrated in figure 3.4.3. The results show a trend for the endurance times to be longer in the older groups. The endurance time in group 1 was significantly shorter than group 5 (P = 0.041). In addition, the endurance time in group 2 was significantly shorter than group 5 (P = 0.028). There was no significant different between other age groups. However, again there was a clear trend for the times to increase until group 5. Once more the spread in data was large. Details are shown in table 3.4.2 and illustrated in figure 3.4.3.

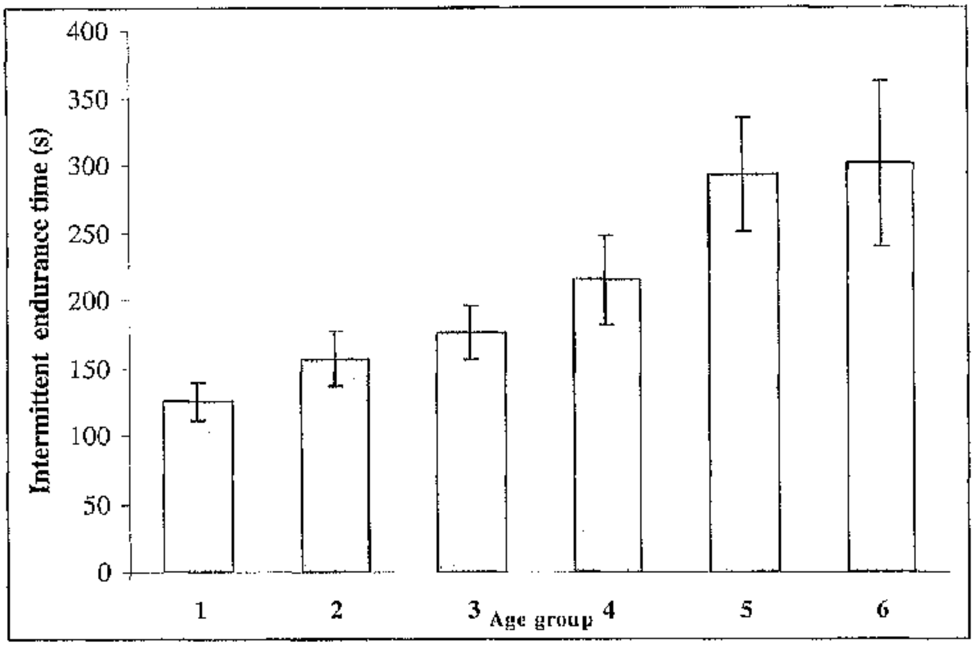


Figure 3.4.3 shows the endurance time of a series of intermittent contractions of flexor muscles of the dominant arm. The columns represent the mean ± SEM of each group female volunteers. The endurance time in group 1 was significantly shorter than group 5 (P= 0.041). In addition, the endurance time in group 2 was significantly shorter than group 5 (P = 0.028). There was no significant difference between other age groups.

EMG median frequency

The surface electromyogram from the belly of the flexor digitorum superficialis was recorded concurrently during the contractions described previously. Details of the recording technique and the EMG processing are given in detail in chapter 2. In particular the median frequency of the EMG was calculated for the first and last 5 seconds of each sustained contraction. In the case of the intermittent contractions, the median frequency of each 5 seconds of activity was calculated. The values are shown in table 3.4.3.

During sustained contractions, the mean median frequency of the age group volunteers was not significantly different in the initial 5 seconds period. Neither were the median frequencies different in age groups at the end of the contraction.

Median Frequencies (Mean ± SEM)						
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
First 5 seconds sustained	86.4± 5.1 (Hz)	84± 3.4 (Hz)	86± 3.2 (Hz)	83.4± 4.9 (Hz)	82.3± 5.7 (Hz)	86.8± 6.7 (Hz)
Last 5 seconds sustained	56.8± 7.2 (Hz)	49.4+ 4.3 (Hz)	38.1± 4.1 (Hz)	43.7± 7.3 (Hz)	55.6± 7.6 (Hz)	49.5± 11.4 (Hz)
Difference	29.6 ± 6.9	34.6 ± 3.3	48 ± 5.3	39.6 ± 3.4	26.4 ± 4.2	37.3 ± 8.3
N*	5	13	9	10	10	6

Table 3.4.3 shows the value of mean median frequency of sustained contraction in different age groups. The columns represent the mean ± SEM of the female volunteers. * Number of volunteers.

In all age groups there was a significant reduction in median frequency ($p < 0.001$).

The same group of volunteers also participated in the intermittent contraction experiment. This was carried out after the sustained contractions and after a recovery period of 10 minutes rest. The recovery of the EMG was complete after 10 minutes rest. The initial median EMG frequencies are not significantly different at the beginning of both tests. Details are shown in tables 3.4.3 and 3.4.4. During intermittent contractions, the mean median frequency of the age groups volunteers was not significantly different in the initial 5 seconds period.

The median frequencies of the first and last contractions are shown in table 3.4.4.

Median Frequencies (Mean ± SEM)						
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
First 5 seconds intermittent	87.8± 5.3 (Hz)	84.2± 3.3 (Hz)	90.7± 3.6 (Hz)	89.1± 5.2 (Hz)	88.6± 4.3 (Hz)	94.8± 6.8 (Hz)
Last 5 seconds intermittent	67.8± 8.3 (Hz)	66.5± 4.1 (Hz)	86.3± 3.5 (Hz)	67.8± 6 (Hz)	74.8± 5.1 (Hz)	81.4± 5.5 (Hz)
Difference	20 ± 4.3	17.7 ± 2.6	14.3± 2.5	21.2 ± 4.7	13.8 ± 3	13.4 ± 3.6
N*	5	13	9	10	10	6

Table 3.4.4 shows the value of mean median frequency of a series of intermittent contraction in different age groups. The columns represent the mean ± SEM of the female volunteers. * Number of volunteers.

In all age groups there was a significant reduction in median frequency ($P < 0.001$).

Half relaxation time

The time for half relaxation was assessed for finger flexors of the dominant arm by determining the time taken for the force to fall from 75 to 25% of the maximum value at the end of each 60% MVE in a series of intermittent contractions. The first and last contractions were measured. The half relaxation time of the first and last contraction and the difference are shown in table 3.4.5. In all age groups there was a substantial increase in half relaxation time. There was no significant difference between the mean half relaxation time in different age groups at the beginning or at the end of the series of intermittent contractions.

Half relaxation time						
Intermittent contractions	Group 1 Mean ± SEM	Group 2 Mean ± SEM	Group 3 Mean ± SEM	Group 4 Mean ± SEM	Group 5 Mean ± SEM	Group 6 Mean ± SEM
First contraction	94.7 ±18.4 (ms)	83.3±5.6 (ms)	93±8.6 (ms)	95.8±18.8 (ms)	124±19.5 (ms)	77.6±13.6 (ms)
Last contraction	143.5±25 (ms)	123.7±7.8 (ms)	144.3±8.6 (ms)	142.7±24 (ms)	162.7±22 (ms)	122.8±23 (ms)
Difference	48 ±11.2	40 ±4.6	51.4±7.5	47±7.6	38.4±5.6	45.2±13.2
N*	5	13	9	10	10	6

Table 3.4.5 shows the half relaxation time of the first and last contractions and their difference of a series of a series of intermittent contractions in different age groups. The columns represent the mean ± SEM of the female volunteers.

* Number of volunteers.

Cardiovascular system

Blood pressure

Systolic and diastolic blood pressure was measured in the dominant arm of all volunteers before (at rest) and immediately after both sustained and a series of intermittent contractions. In addition, heart rate was recorded in all volunteers simultaneously with blood pressure.

The mean systolic and diastolic blood pressure before contractions and after both sustained and a series of intermittent contractions show a progressive increase with age. There were significant differences within age groups. This is illustrated in figures 3.4.4 and 3.4.5. These changes are what might be expected.

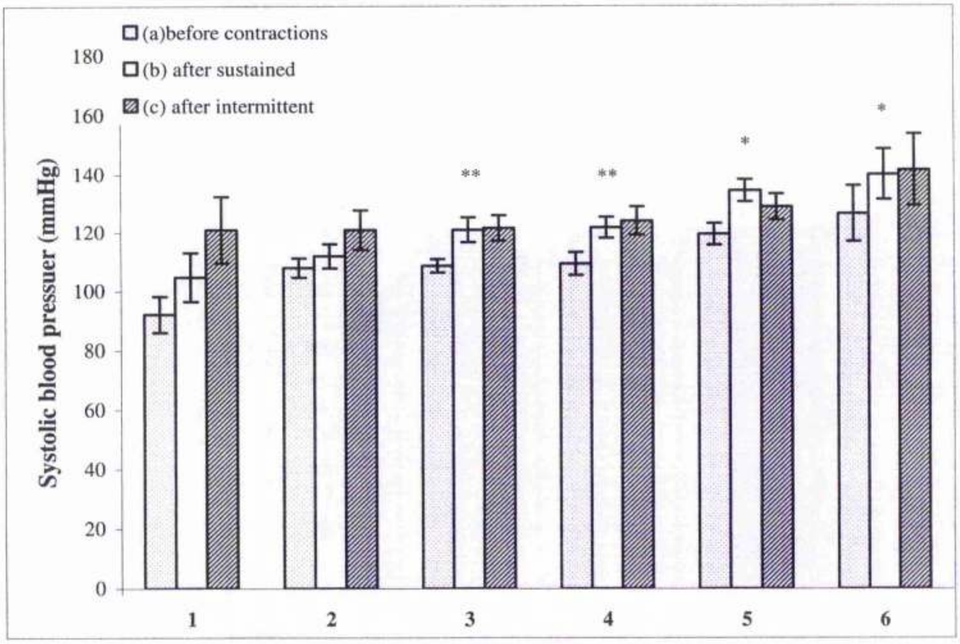


Figure 3.4.4 shows the systolic blood pressure of the dominant arm before contractions (**a**), after sustained contraction (**b**) and after intermittent contractions (**c**). The columns represent the mean ± SEM of each female group volunteers.

(**a**) The mean systolic blood pressure in group 1 was significantly different from the groups 5 (P = 0.006) and 6 (P = 0.001). There were no significant differences between the mean systolic blood pressure in other groups.

(**b**) The mean systolic blood pressure after sustained contraction in group 1 was significantly different from groups 5 (P = 0.007) and 6 (p = 0.003). In addition the mean systolic blood pressure after sustained contraction in females in group 2 was significantly different from mean systolic blood pressure in groups 5 (P = 0.007) and 6 (p = 0.004). There were no significant differences between the mean systolic blood pressure in other groups.

(**c**) The mean systolic blood pressure after intermittent contractions was not significantly different between groups.

Asterisks show significant difference between BP at rest and after contractions in each group. * P < 0.05 and ** P< 0.001.

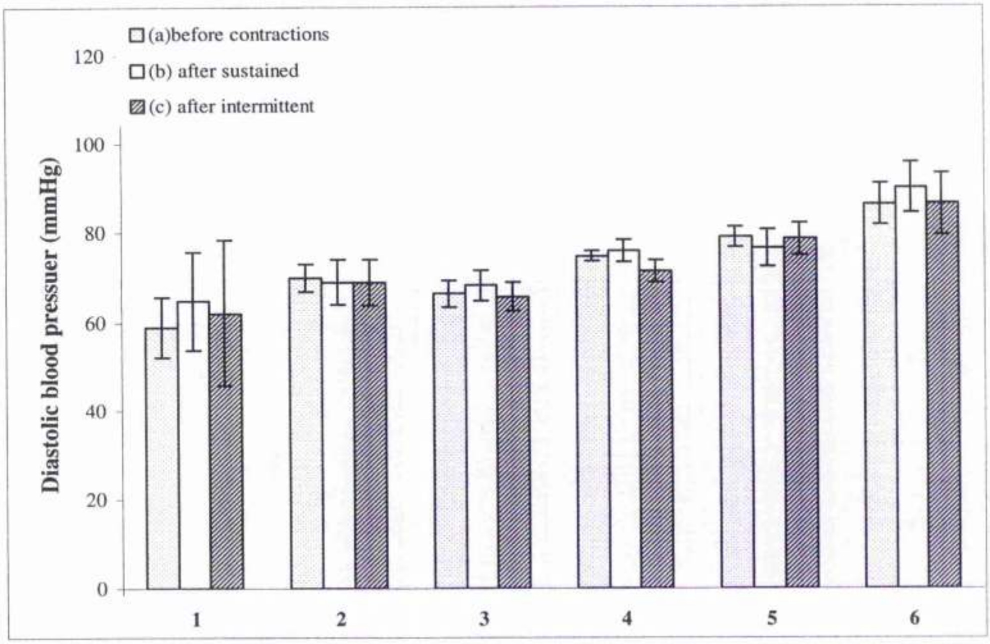


Figure 3.4.5 shows the diastolic blood pressure of the dominant arm before contractions (**a**), after sustained contraction (**b**) and after intermittent contractions (**c**). The columns represent the mean ± SEM of each female group volunteers.

(**a**) Shows the mean diastolic blood pressure in group 1 was significantly different from the groups 4 to 6 ($P \leq 0.004$). In addition, the mean diastolic blood pressure in group 2 was significantly different from mean diastolic blood pressure in group 6 ($P = 0.014$). The mean diastolic blood pressure in group 3 was significantly different from mean diastolic blood pressure in group 6 ($P = 0.003$). There were no significant differences between the mean diastolic blood pressure in other groups.

(**b**) and (**c**) show there were no significant differences between the mean diastolic blood pressure after sustained and a series of intermittent contractions in different age of females.

Heart rate

In addition to systolic and diastolic blood pressure, heart rate was measured in the dominant arm of all volunteers before (at rest) and soon after both sustained and intermittent contractions in all volunteers at the same time with blood pressure.

There were no significant differences between the mean heart rate in different female age groups. Results are shown in below (table 3.4.6). A full list of measurements and their changes is shown in appendix 4.

Heart rate (bpm)						
	Group 1 Mean ± SEM	Group 2 Mean ± SEM	Group 3 Mean ± SEM	Group 4 Mean ± SEM	Group 5 Mean ± SEM	Group 6 Mean ± SEM
Before contractions	73.4 ± 6 (bpm)	71.1 ± 3.6 (bpm)	65.6 ± 4.4 (bpm)	72.5 ± 4.3 (bpm)	74.9 ± 2.8 (bpm)	79.8 ± 6.6 (bpm)
After sustained	88.4 ± 3.6 (bpm)	66.4 ± 4.1 (bpm)	68.9 ± 5.1 (bpm)	70.1 ± 5.5 (bpm)	72.3 ± 3.3 (bpm)	76.7 ± 7.2 (bpm)
After intermittent	76.4 ± 6.3 (bpm)	77.8 ± 3.6 (bpm)	66.4 ± 4.7 (bpm)	73.8 ± 5 (bpm)	72.3 ± 3.3 (bpm)	80.2 ± 6.1 (bpm)
N*	5	13	9	10	10	6

Table 3.4.6 shows the mean heart rate before contractions (at rest), immediately after the sustained and a series of intermittent contractions in different age groups. The columns represent the mean ± SEM of the female volunteers. There were no significant differences within age groups. * Number of volunteers.

3.5 Comparison of male characteristics between age groups:

The main aim of this section was to investigate age related changes in males.

The analysis compares data for each age group of male volunteers. To facilitate this the data were divided into 6 age groups. Details are shown in table 3.5.1. It can be seen that the height increases progressively in group 1, 2, and 3. The weight increases with age.

Group	Age range	Number of volunteers	Age Mean ± SEM (year)	Height Mean ± SEM (m)	Weight Mean ± SEM (Kg)
1	5 to 9	5	7.2 ± 0.8	1.30±0.05	25.6 ± 2.1
2	10 to 19	13	12.7 ± 0.3	1.57±0.03	47.8 ± 2.8
3	20 to 29	9	22.2 ± 0.7	1.78±0.02	75.3 ± 3.2
4	30 to 39	10	35.4 ± 0.8	1.76±0.02	80.4 ± 5
5	40 to 49	10	44.6 ± 1.1	1.79±0.03	85.9 ± 4.8
6	> 50	8	57.8 ± 1.9	1.82±0.03	86.1 ± 4.6

Table 3.5.1 shows the age range and the mean age, height and weight ± SEM of males in different age groups. The number of volunteers is shown in each age group.

Statistics

The data for age groups were compared using one-way analysis of variance. There were significant differences between age groups. Tukey's HSD follow up test was used. A full list of measurements and their changes is shown in appendix 5.

Some age related changes were clearly significant. For example the mean grip force illustrated in figure 3.5.1 shows a progressive rise through groups 1, 2 and 3. The grip force then shows no significant change with age.

The mean of the maximum voluntary grip was calculated for each age group. The lowest maximum voluntary grip was group 1 and the highest maximum voluntary grip was seen in group 3. There were significant differences between mean maximum voluntary grip in group 1 with groups 3, 4, 5 and 6 (P values < 0.0001). In addition the mean MVE in group 2 was significantly lower than group 3 ,4,5 and 6 (P values < 0.0001). There were no significant differences between other groups in terms of mean MVE. Details are shown in table 3.5.2 and figure 3.5.1.

Group	MVE (N) Mean ± SEM	Sustained endurance (s) Mean ± SEM	Intermittent endurance (s) Mean ± SEM	N*
1	140 ± 24	43.8 ± 8	131 ± 14.8	5
2	254 ± 29	46.31 ± 7.3	168.8 ± 28.5	13
3	584 ± 31	61 ± 3.4	146.2 ± 11.4	9
4	528 ± 26	58.3 ± 5.2	163.6 ± 15.1	10
5	526 ± 24	60.3 ± 3.9	198.5 ± 48.6	10
6	519 ± 37	56.4 ± 6.6	180 ± 18.5	8

Table 3.5.2 shows the MVE, endurance time of sustained contraction and endurance time of a series of intermittent contractions in 6 different age groups. The columns represent the mean ± SEM of the male volunteers. * Number of volunteers.

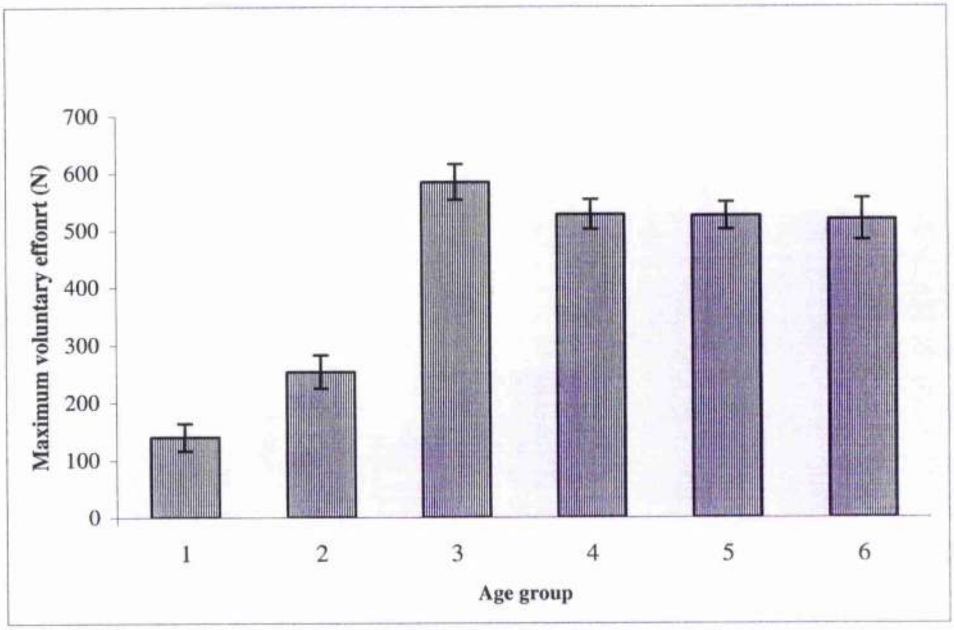


Figure 3.5.1 shows the maximum voluntary force in the finger flexor muscles of the dominant arm. The columns represent the mean ± SEM of each group male volunteers. The mean MVE in group 1 was significantly different from the groups 3 to 6 ($P < 0.0001$). In addition the mean MVE in group 2 was significantly different from mean MVE in groups 3 to 6 ($p < 0.0001$).

There were no significant differences between the mean MVE in other groups.

Endurance time

a) Sustained contraction

The endurance time of sustained contractions was measured and the mean ± SEM was calculated for different age groups. Details are shown in table 3.5.2 and illustrated in figure 3.5.2. The shortest endurance time was seen in group 1 and the longest time was in group 3. Details are shown in table 3.5.2. There were no significant differences between age groups.

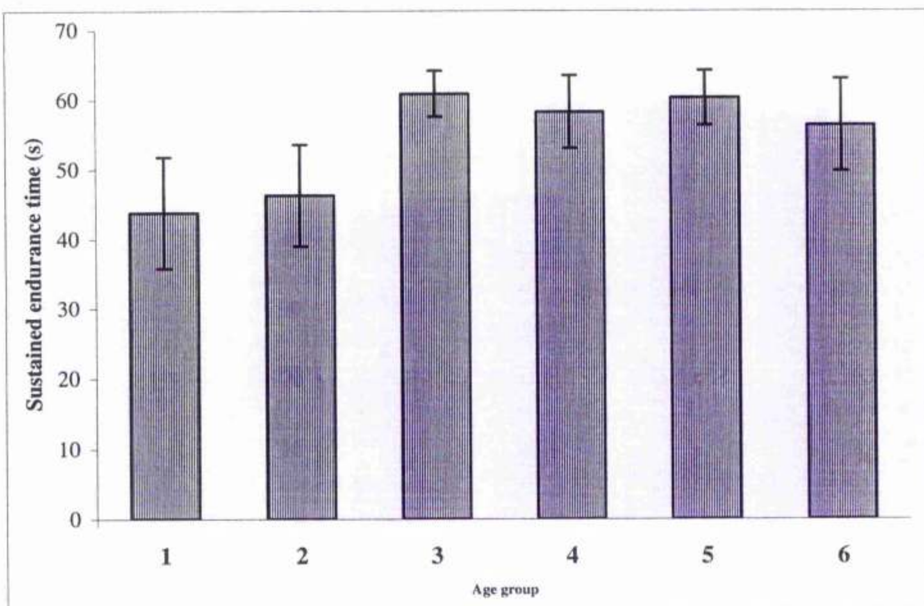


Figure 3.5.2 shows the endurance time in sustained contraction of flexor muscles of the dominant arm. The columns represent the mean ± SEM of each male volunteer group. There were no significant differences between the mean endurance time in six age groups.

b) Intermittent contractions

The endurance time of intermittent contractions was measured in all 6 groups. Details are shown in table 3.5.2 and illustrated in figure 3.5.3. The results show a trend for the endurance times to be longer in the older groups. There was no significant different between the age groups. However, again there was a clear trend for the times to increase until group 5. Once more the spread in data was large. Results are shown in table 3.5.2 and illustrated in figure 3.5.3.

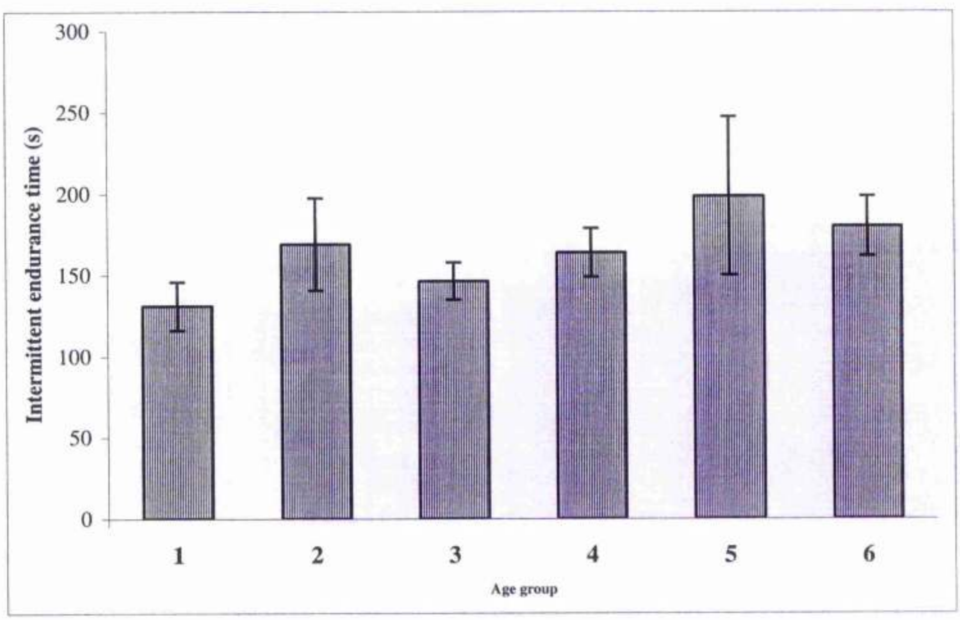


Figure 3.5.3 shows the endurance time of a series of intermittent contractions of flexor muscles of the dominant arm. The columns represent the mean ± SEM of each group male volunteers.

There was no significant different between the age groups.

EMG median frequency

The surface electromyogram from the belly of the flexor digitorum superficialis was recorded concurrently during the contractions described previously. Details of the recording technique and the EMG processing are given in detail in chapter 2. In particular the median frequency of the EMG was calculated for the first and last 5 seconds of each sustained contraction. In the case of the intermittent contractions, the median frequency of each 5 seconds of activity was calculated. The values are shown in table 3.5.3.

During sustained contractions, the mean median frequency of the age groups volunteers was not significantly different in the initial 5 seconds period. Neither were the median frequencies different in age groups at the end of the contraction.

Median Frequencies (Mean ± SEM)						
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
First 5 seconds sustained	79.8± 5.2 (Hz)	96.7±5.1 (Hz)	88±6.2 (Hz)	78.8± 4.4 (Hz)	78.8± 5 (Hz)	89± 7.6 (Hz)
Last 5 seconds sustained	61.2± 1.7 (Hz)	64.3± 7.2 (Hz)	42.2± 3.9 (Hz)	41± 6.3 (Hz)	39.4± 6.3 (Hz)	49.2± 6.8 (Hz)
Difference	18.6 ± 6.8	32.4 ± 5.1	45.8 ± 4	37.8 ± 3.9	39.4 ± 5.4	39.7 ± 7.5
N*	5	13	9	10	10	8

Table 3.5.3 shows the value of mean median frequency of sustained contraction in different age groups. The columns represent the mean ± SEM of the male volunteers. * Number of volunteers. In all age groups there was a substantial reduction in median frequency.

The same group of volunteers also participated in the intermittent contraction experiment. This was done after the sustained contractions and after a recovery period of 10 minutes rest. The recovery of the EMG was complete after 10 minutes rest. The initial median EMG frequencies are not significantly different at the beginning of both tests. Details are shown in tables 3.5.3 and 3.5.4. During intermittent contractions, the mean median frequency of the age groups volunteers was not significantly different in the initial 5 seconds period. Neither were the median frequencies different in age groups at the end of the contraction.

The median frequencies of the first and last contractions are shown in table 3.5.4.

Median Frequencies (Mean ± SEM)						
	Group 1	Group 2	Group3	Group 4	Group 5	Group 6
First 5 seconds intermittent	83.6± 3.4 (Hz)	98.7± 6.3 (Hz)	92.1±4.4 (Hz)	79.7±6.1 (Hz)	82.8± 5.5 (Hz)	94.2± 7.3 (Hz)
Last 5 seconds intermittent	70.3± 3.1 (Hz)	78.6± 7.3 (Hz)	72.4± 3.5 (Hz)	52.7±6.6 (Hz)	59.6± 5.9 (Hz)	72.9± 8.1 (Hz)
Difference	13.3 ± 2	20 ± 3.3	19.7± 2.5	27 ± 5.1	23.2 ± 2.2	21.2 ± 3.2
N*	5	13	9	10	10	8

Table 3.5.4 shows the value of mean median frequency of intermittent contractions in different age groups. The columns represent the mean ± SEM of the male volunteers. *N number of volunteers. In all age groups there was a substantial reduction in median frequency. This indicates a strong fatigue state.

Half relaxation time

The time for half relaxation was assessed for finger flexors of the dominant arm by determining the time taken for the force to fall from 75 to 25% of the maximum value at the end each 60% MVE in a series of intermittent contractions. The first/last contractions were measured. The half relaxation time of the first and last and the difference are shown in table 3.5.5. In all age groups there was a substantial increase in half relaxation time. This indicated a strong fatigue state. There was no significant difference between the mean half relaxation time in different age groups at the beginning or at the end of the series of intermittent contractions.

Half relaxation time						
Intermittent contractions	Group 1 Mean ± SEM	Group 2 Mean ± SEM	Group 3 Mean± SEM	Group 4 Mean ± SEM	Group 5 Mean ± SEM	Group 6 Mean ± SEM
First contraction	88 ± 10 (ms)	84.7±9.7 (ms)	94±1.2 (ms)	81 ± 11 (ms)	95.2 ± 11 (ms)	109 ±19.9 (ms)
Last contraction	137 ± 20 (ms)	122.6±9.9 (ms)	150.3±4.5 (ms)	165.6 ± 5.2 (ms)	138 ±14.8 (ms)	161 ± 2.6 (ms)
Change	49 ± 14	37.8 ±9.5	68.5±10.9	84.6 ± 6.9	42.8 ± 8.1	51.8±12.7
N*	5	13	9	10	10	8

Table 3.5.5 shows the half relaxation time of the first and last contractions and their difference of a series of a series of intermittent contractions in different age groups. The columns represent the mean ± SEM of the male volunteers. * Number of volunteers.

Cardiovascular system

Blood pressure

Systolic and diastolic blood pressure was measured in the dominant arm of all volunteers before and soon after both sustained and intermittent contractions. In addition, heart rate was measured in all volunteers at the same time with blood pressure.

The mean systolic and diastolic blood pressure before contractions and after both sustained and intermittent contractions show a progressive increase with age. This is illustrated in figures 3.5.4 and 3.5.5. These changes are what might be expected.

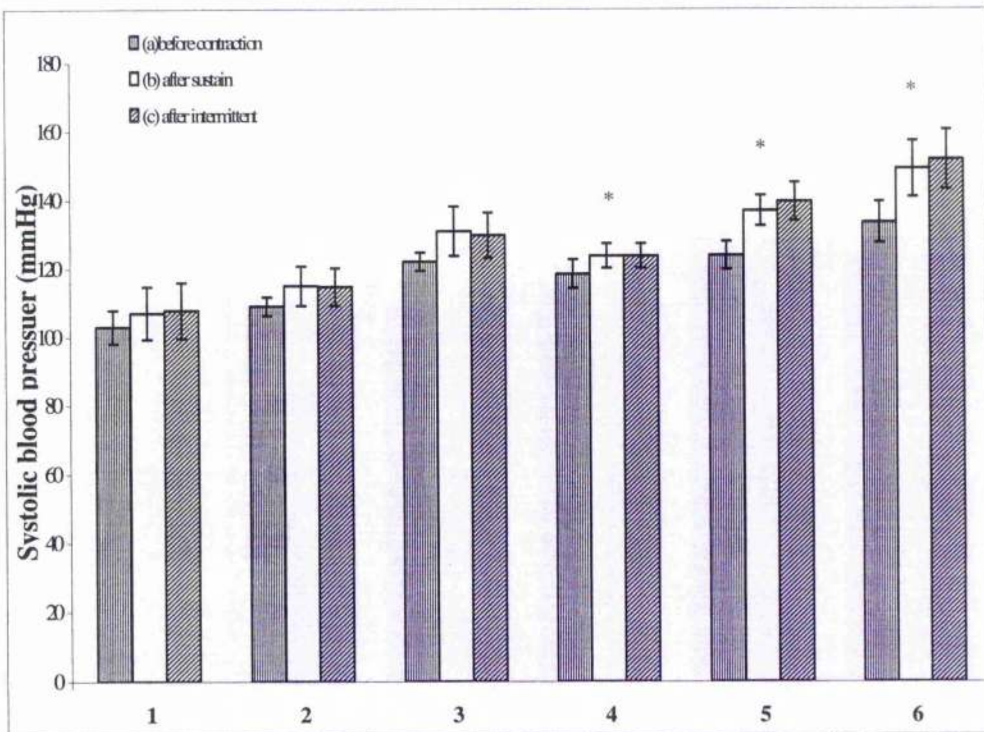


Figure 3.5.4 shows the systolic blood pressure of the dominant arm before contractions (**a**), after sustained contraction (**b**) and after intermittent contractions (**c**). The columns represent the mean ± SEM of each male group volunteers.

(**a**) The mean systolic blood pressure in group 1 was significantly different from the groups 5 ($P = 0.024$) and 6 ($P = 0.001$). In addition the mean systolic blood pressure in group 2 was significantly different from the groups 5 ($P = 0.04$) and 6 ($P = 0.001$). There were no significant differences between the mean systolic blood pressure in other groups.

(**b**) The mean systolic blood pressure after sustained contraction in group 1 was significantly different from group 6 ($p = 0.003$). In addition the mean systolic blood pressure after sustained contraction in males in group 2 was significantly different from mean systolic blood pressure in group 6 ($p = 0.002$). There were no significant differences between the mean systolic blood pressure in other groups.

(**c**) The mean systolic blood pressure after intermittent contractions in group 1 was significantly different from the groups 5 ($P = 0.037$) and 6 ($P = 0.003$). In addition the mean systolic blood pressure in group 2 was significantly different from the groups 5 ($P = 0.031$) and 6 ($P = 0.001$). There were no significant differences between the mean systolic blood pressure after intermittent contractions in other groups. Asterisk shows significant difference between BP at rest and after contractions in each group. * $P < 0.05$.

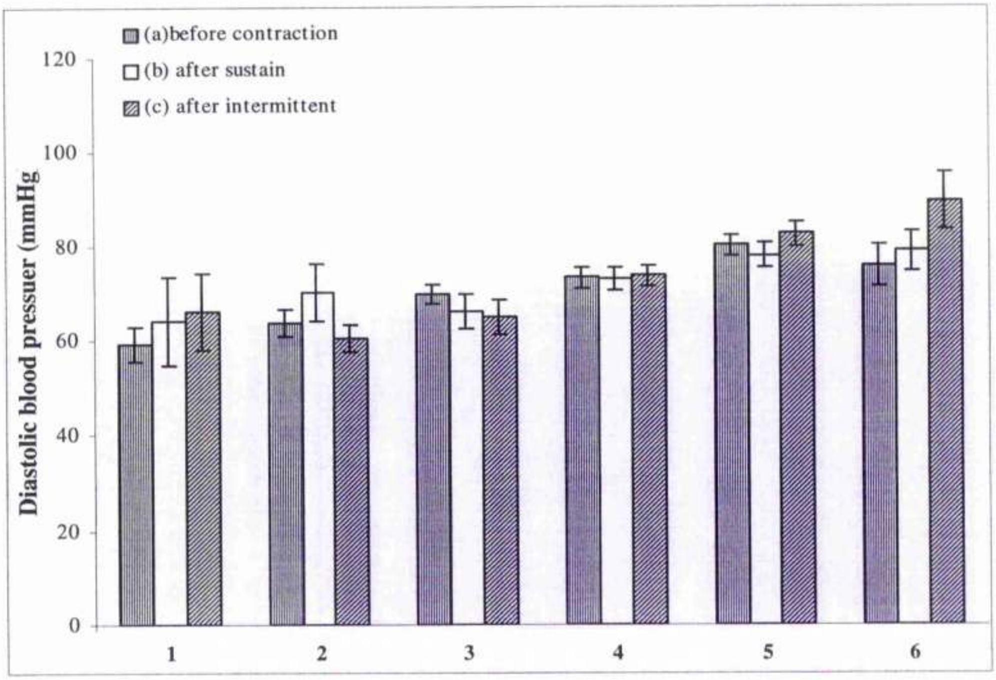


Figure 3.5.5 shows the diastolic blood pressure of the dominant arm before contractions (**a**), after sustained contraction (**b**) and after intermittent contractions (**c**). The columns represent the mean ± SEM of each male group volunteers.

(**a**) The mean diastolic blood pressure in group 1 was significantly different from the groups 5($P = 0.001$) and 6 ($P = 0.025$). In addition, the mean diastolic blood pressure in group 2 was significantly different from mean diastolic blood pressure in groups5 ($P =0.001$) and 6 ($P < 0.05$). There were no significant differences between the mean diastolic blood pressure in other groups.

(**b**) There were no significant differences between the mean diastolic blood pressure after sustained contraction in different age of males.

(**c**) The mean diastolic blood pressure after a series of intermittent contractions in group 1 was significantly different from the group and 6 ($P = 0.012$). In addition, the mean diastolic blood pressure in group 2 was significantly different from mean diastolic blood pressure in groups5 ($P =0.001$) and 6 ($P < 0.0001$).

The mean diastolic blood pressure after intermittent contractions was significantly different between group 3 with groups5 ($P = 0.035$) and 6 ($P = 0.002$)

Heart rate

In addition to systolic and diastolic blood pressure, heart rate was measured in the dominant arm of all volunteers before (at rest) and soon after both sustained and intermittent contractions in all volunteers at the same time as blood pressure.

There were no significant differences between the mean heart rate in different male age groups. Details are shown in below (table 3.5.6).

Heart rate (bpm)						
	Group 1 Mean ± SEM	Group 2 Mean ± SEM	Group 3 Mean ± SEM	Group 4 Mean ± SEM	Group 5 Mean ± SEM	Group 6 Mean ± SEM
Before contractions	89.4 ± 5.4 (bpm)	74.5 ± 3.6 (bpm)	62 ± 3.6 (bpm)	70.2 ± 3.8 (bpm)	70.6 ± 2.9 (bpm)	68 ± 7.3 (bpm)
After sustained	92.6 ± 8.4 (bpm)	76.7 ± 3.1 (bpm)	62.6 ± 4.8 (bpm)	71.9 ± 4.1 (bpm)	70.2 ± 3.7 (bpm)	70.4 ± 6.6 (bpm)
After intermittent	94.8 ± 4.8 (bpm)	78.8 ± 3.4 (bpm)	63.7 ± 5.5 (bpm)	74.8 ± 5 (bpm)	68.1 ± 3.3 (bpm)	69.6 ± 7 (bpm)
N*	5	13	9	10	10	8

Table 3.5.6 shows the mean heart rate before contractions (at rest), immediately after the sustained and intermittent contractions in different age groups. The columns represent the mean ± SEM of the male volunteers. There were no significant differences within age groups. * Number of volunteers.

CHAPTER 4

Discussion

The characteristics of EMG during muscle fatigue have been investigated in 108 healthy volunteers aged between 5 to 65 years. Female and male volunteers were tested.

In this study EMG was recorded from finger flexors in the dominant arm during sustained contractions and during a series of intermittent contractions. These recordings have been made at 60% of maximum grip force. The EMG has been subjected to conventional analysis to show changes in intensity and frequency content. These data have been used to address several previously unanswered questions about how fatigue characteristics are affected by sex and age:

1- Is the mean median frequency of the EMG spectrum affected by the age and sex of the volunteers?

2-Is the time to voluntary force failure affected by the age and sex of the volunteers?

3-Is the relaxation rate after contractions affected by the age and sex of the volunteers?

4-Do the age and sex of the volunteers affect the blood pressure and heart rate changes during fatiguing contractions?

4.1 Comparison of characteristics between age groups

Despite an abundance of studies that have examined fatigue, relatively few studies have investigated the effect of ageing on fatigability. In contrast, age-related alterations in the structure of skeletal muscle, such as losses in muscle mass, motor unit (MU) and fibre number, and MU remodelling, have been well described (Luff, 1998; Lowe, Degens, Chen and Alway, 2000; Vandervoort, 2002). Around the age of 40, healthy human subjects begin to lose muscle force generation capacity (Bemben et al., 1991; Merletti et al., 1992b; Thompson, 1994). Furthermore, age related changes in the contractile properties and proteins have been characterised (Rice, 2000).

The functional consequences of these age-related alterations include substantial loss of strength and slowed contractile characteristics in most muscles tested (Hunter, White and Thompson, 1998). It has been proposed that with advanced age (≥70 years) type I fibres contribute proportionally more to force generation than in younger adults (Roos et al., 1997). Thus, based on these MU remodelling changes, it seems reasonable to hypothesize that aged subjects will demonstrate reduced muscle fatigability (i.e., increased endurance capacity) during tests of endurance that require the same relative level of strength production in both age groups. However, this result has not been found consistently from the limited number of studies available, and indeed some studies report no age-related fatigue difference, whereas in others, aged subjects are more fatigable than young subjects. These varied results have made it impossible to make definitive statements or consensus about the effect of ageing on endurance capacity (Allman and Rice, 2002).

In addition to the confounding effects of the age, gender and physical activity status of the subjects characterised as elderly, some of the apparent inconsistencies found when studies are compared may be explained by differences in the fatigue task performed. This is because the mechanisms inducing fatigue rely strongly on the fatigue task used, i.e., are task-dependent (Bigland-Ritchie et al., 1995). Such task-related variability may arise due to performance of different exercise types, voluntary or electrically stimulated, isometric or dynamic, sustained or intermittent, high or low forces. In addition the exercise paradigms may use muscles of differing contractile properties (Bigland-Ritchie et al., 1995). Ageing also has been shown to result in decreased cortical and muscle membrane excitability (Hicks et al., 1992), an uncoupling of excitation-contraction (EC) mechanisms and altered metabolic capacity (Pastoris, Boschi, Verri, Baiardi, Felzani, Vecchiet, Dossena and Catapano, 2000). Each of these changes could influence the comparative fatigability of young versus old humans, irrespective of the role of MU remodelling. However, the extent to which these factors affect the response of the neuromuscular system to prolonged sustained or intermittent muscle activity is not well understood and indeed may be related to the required task. A comprehensive and descriptive understanding of these factors is necessary because fatigue, and the ability to recover from fatigue, may be fundamental in determining whether aged humans can perform and repeat requisite movements successfully. These are important factors that relate ultimately to the ability of aged people to live meaningful and independent lives.

EMG median frequency

The fatigue has been assessed in 6 age groups between 5 and above 50 years of age. The initial median frequency during the first 5 seconds of a contraction and the final median frequency during the final 5 seconds of contractions were calculated.

In all age groups and in both sustained and intermittent contractions the mean initial median frequency was significantly greater than the mean final median frequency ($P < 0.0001$). These data are shown in figure 3.3.4 and appendix 3. Initial and final frequencies are similar to those reported in other muscles by Melzer, Benjuya and Kaplanski, (2000). The changes during sustained contractions were approximately twice as large as those in intermittent contractions even though both were continued to volitional exhaustion. The intermittent contractions lasted approximately three times longer than the sustained contractions. The fatigue mechanisms cannot be identical but they share some similarities. It is likely that the blood flow during the 5 seconds relaxation periods allows some recovery of the supply of oxygen and the removal of metabolites. However, no significant age-related changes in initial and final median frequency in both types of contractions were observed. This is similar to the study published by Melzer, et al (2000). They tested eighty subjects (35 females and 45 males) in 4 age groups between 20 to 60 years of age. There was no age and gender difference in electromyographic measurements in median frequency of vastus lateralis and vastus medialis in their study. Their result showed a distinct difference between age groups in muscle strength.

It is well known that there is a selective loss of type II fibres with increasing age. Lexell et al. (1988) found 10% atrophy in vastus lateralis muscle between 24 and 50 years of age. Their results showed that the ageing atrophy of this muscle begins around 25 years of age and thereafter accelerates. This reduces fibre diameter and conductive velocity. They claimed that most of the atrophy was located in fast twitch muscle fibres (large muscle fibres), with a decrease in the velocity of contraction. Merletti et al. (1992) explained a lesser decrease in median frequency with fatigue of the tibialis anterior muscle in elderly (65 to 84 years) compared with young subjects by the preferential loss or atrophy of type II fibres with advancing age.

Different muscles atrophy / composition was too small to see with this work EMG technique.

With regard to the use of electromyography to assess fatigue, it should be pointed out that both increase in amplitude of EMG signal and the frequency shift of the power spectrum are related. The local accumulation of metabolites results in a decrease in conduction velocity, resulting in larger time duration of the motor unit waveforms. Both frequency shift and amplitude increase are indicators of metabolic events going on within a muscle, although signal amplitude has a reduced sensitivity compared to frequency shift (Basmajian and De Luca, 1985).

The ranges for the both initial median frequency (IMF) and final median frequency (FMF) for isometric contraction at 60% MVE have been evaluated. Details are shown in tables 3.3.3 and 3.3.4.

Several studies have reported mean values for median frequency in various muscles in healthy volunteers as part of studies investigating various characteristics of MF (Sanders, Stalberg and Nandedkar, 1996; Fugslang-Frederiksen, 2000; Finsterer, 2001). However, each researcher has used a different protocol, performing contractions at levels of force varying from 25% to 80% of MVE, and using surface electrodes of varying diameters to record the EMG signal. None of these investigators have specifically attempted to define a set of normal values.

The biceps brachii muscle has been studied most frequently. Published data include a mean ± standard deviation IMF of 108 ± 32 Hz at 80% MVE (Linssen et al., 1993), an initial mean frequency of 135 Hz decaying to 89.5 Hz after a 60-seconds contraction at 50% MVE Moritani et al. 1986, a mean initial frequency of 119 Hz at 40% MVE (Moritani, Murro and Nagata, 1982), and an IMF of 58 to 89 Hz at 15% MVE (Krogh-Lund and Jorgensen, 1992). Although Moritani et al. (1982) used 50% of MVE, they looked at the mean rather the median frequency. The mean frequency is usually higher than the median frequency. Gerdle et al. (1990) showed that interelectrode distance had little effort on the IMF in biceps or on its decline with fatigue.

Other muscles for which results have been published include the brahialis, with an IMF of 46 to 81 Hz at 30% MVE (Krogh-Lund and Jorgensen, 1993b); the brachioradialis, with an IMF of 60 to 90 Hz at 15% MVE (Krogh-Lund and Jorgensen, 1992); the triceps, with an IMF of 40 to 73 Hz at 25% MVE (Krogh-Lund and Jorgensen, 1991); the biceps 90 ± 18 Hz and triceps 85 ± 18 Hz at 50% MVE .

Cooling isolated canine diaphragm preparations with intact neurovascular supply from 40 to 30° C resulted in a linear decrease of the median frequency (Doud and Walsh, 1993).

In conclusion factors such as MFCV, motor unit firing rates, recruitment, motor unit synchronisation and the shape of the motor unit action potentials and intramuscular temperature all potentially change during a fatiguing contraction. The EMG signal is sensitive to all these factors. Furthermore, local motor units located in the vicinity of the recording electrodes dominate the surface EMG signal and factors such as electrode location and orientation can affect the accuracy of MFCV measurements (Merletti et al., 1999).

Perhaps the summed effect of all these factors is too variable to allow an age related change to be detected with the sample size used in this project.

Endurance time

There were no significant differences in the endurance time of sustained contraction between the age groups (P = 0.097). This can be seen in table 3.3.2 and appendix 3. There was a clear trend for longer endurance times in older groups. However, large standard deviation of data made it difficult to identify a statistically significant result. In intermittent contractions the results show that as age increases, the endurance time of contractions increases (P = 0.008). The endurance time in group 1 was significantly shorter than group 5 (P = 0.029). There was no significant different between other age groups. However, again there was a clear trend for the times to increase until group 5.

It can be concluded that with increase in age the endurance time increases up to age 50. This is consistent with a relatively larger fraction of the muscle area occupied by type I fibres as reported by Narici et al (1991).

Despite extensive research on age-related changes in neuromuscular morphology and function (Roos et al., 1997; Luff, 1998), fatigue studies in old humans and especially in children between 6 to 16 years of age (Jones and Stratton, 2000) have been few in number, providing limited insight into age-related alternations in fatigue and recovery mechanisms. Most studies have tested fatigue using intermittent maximal contractions, and results suggest there is no clear difference in fatigability between young and old individuals (Hicks et al., 1992; Bemben et al., 1996; Lindstrom, Lexell, Gerdle and Downham, 1997).

An increase in isometric endurance with old age (after the age of 50 years) has been reported previously (Narici et al., 1991) and would be consistent with a relatively larger muscle volume (area) occupied by type I fibres, which are more resistant to fatigue.

Half relaxation time

The time for half relaxation of grip force was assessed by determining the time taken for the force to fall from 75 to 25% of 60% of MVE at the end of contractions (Lyons and Aggarwal, 2001).

The first and last contractions were measured. The initial half relaxation time of all age groups was significantly shorter than the final half relaxation time ($P < 0.0001$).

There was no significant difference between the mean half relaxation time in different age groups at the beginning or at the end of the series of intermittent contractions.

A similar study of the effect of age on half relaxation times has recently been published (Bilodeau, Henderson, Nolta, Pursley and Sandfort, 2001). They tested elbow flexor muscles on ten young (26.3 years 5 women, 5 men) and nine elderly (70.8 years 4 women, 5 men). They did not observe an age-related slowing of half relaxation time. However, it is possible that a difference in half relaxation time between young and elderly subjects does exist but it is too small to be detected because of our small population sample in this study and that of Bilodeau and his colleagues.

Davies, White and Young (1983) found uniformity of muscle function in children and adults and suggested that the force generation capacity ($N.cm^2$), fatigueability, speed of contraction and relaxation and force/frequency characteristic of the triceps surae remain unchanged through adolescence and early adulthood.

It should be noted that age-related differences in the contraction speed of human muscle and its change with fatigue have been explained not only by a change in fibre-type distribution, but also by alterations in specific Excitation -Contraction-Relaxation coupling mechanisms (Vandervoort and McComas, 1986; Klein et al., 1988), such as Ca^{2+}-dependent sarcoplasmic reticulum function, or a combination of both factors (Roos, Rice and Vandervoort, 1999). Therefore, both fibre-type content and Excitation-Contraction-

Relaxation coupling can contribute to changes in contraction speed independently, and their respective contribution will most likely vary between different muscles. This could explain the fact that not all variables showed the same age-related differences for finger flexors in the present study and the observation of greater slowing of muscle relaxation in elderly compared with young subjects for other muscle groups (Klein et al., 1988).

On average the magnitude of half relaxation time was larger than expected for all age groups 93 ± 4 msec for initial and 140 ± 5 msec for final half relaxation time. Details are shown in table 3.3.5.

Surprisingly, no studies on the finger flexor muscle group could be found in the literature.

Previous workers (Edwards et al., 1972) found half relaxation time of 30.6 msec for quadriceps muscle, 30.0 msec for the first dorsal interosseous muscle and 29.3 msec for flexor pollicicis brevis, these values rising by a factor of two or three with fatigue. The longer duration found in the present study was unlikely to be due to a slow response rate in recording instruments (see chapter 2), and some other explanation is required. One possibility for this longer duration is the use of electrical stimulation to test twitch characteristics in many published papers whereas in this study relaxation after voluntary contractions was measured. It is also possible that the long tendons attached to these muscle slow the force changes. It may be that the release of the strength gauge handles was slow. On the other hand different muscle group thus different type fibre have been involved in different studies. It is reasonable to assume that the changes in half relaxation time values reflect the real mechanical properties of the muscle-tendon unit. The other explanation is that the surface electrodes did not detect all the activity on the finger flexors and some undetected activity remained, effectively slowing the rate of relaxation. One difference between the finger flexors muscle and those cited above is that the mechanical system to which they are linked is more complex. There are more muscles involved in controlling movement, with more complex control of relaxed or postural position. At the higher target force, fatigue will develop simultaneously in both type I and in the active type II fibres, and the dominance of unfatigued type II fibres on contractile speed will be decreased. In consequence, the temporal changes in muscle activation pattern would predict a lesser decline in half relaxation time during exercise at higher target force (Bakels and Kernell, 1993). An alternative and simpler explanation is that the volunteers were not consciously relaxing as quickly as possible.

In addition to the reduction in electrically stimulated twitch and tetanic forces, ageing is often associated with contractile slowing, reported as an increase in relaxation time of an evoked or voluntary response (Roos et al., 1997). Peripheral factors responsible for contractile slowing may include a combination of alterations in sarcoplasmic reticulum calcium kinetics (Margreth, Damiani and Bortoloso, 1999), increased expression of slow myosin isoforms, or a larger relative type I fibre area found with increasing age (Hunter et al., 1998). Compared with younger adults, the greater degree of fusion in muscle from aged subjects at low frequencies of stimulation (leftward shift) would result in their greater fatigability (Ditor and Hicks, 2000). Because not all human limb muscles demonstrate the same degree of age-related morphological and contractile alterations

(Hunter et al., 1998), different muscle groups in aged adults may be more susceptible to fatigue at low stimulation frequencies. Thus, the importance of defining the task utilised in the fatigability comparison is evident because the age-related shift toward a muscle more dependent on type I fibres and slower contractile properties has been suggested to improve fatigue resistance in one task (e.g., normalised voluntary contractions), yet is likely involved in the decreased fatigue resistance in another (e.g., low-frequency stimulation).

Cardiovascular system

Systolic and diastolic blood pressure was measured in the dominant arm of all volunteers before (at rest) and immediately after both sustained and intermittent contractions. In addition, heart rate was measured in all volunteers at the same time as blood pressure.

The mean systolic and diastolic blood pressure before contractions and after both sustained and intermittent contractions show a progressive increase with age. The average of systolic blood pressure before contractions was significantly lower than the average blood pressure after sustained and a series of intermittent contractions ($P < 0.0001$). This is illustrated in figures 3.3.5 and 3.3.6. These changes are what might be expected.

There was a significant difference between mean heart rate in groups before contractions ($P = 0.037$). In addition the mean heart rate after sustained contraction in age group was significantly different between age groups. Details are shown in table 3.3.6.

The results showed that the blood pressure and heart rate responses within the first and second groups (under 19 years old) do not show a significant difference before and after both contractions. In other age groups in both sexes there was a significant difference in the systolic blood pressure before and after the contractions. However there were no significant difference in the diastolic BP and HR before and after contractions

In general, two basic, and possibly redundant, mechanisms dominate thinking about blood pressure and exercise. Since blood pressure and also respiration increases immediately with the onset of contractions, one suggestion is that there is a feed-forward 'central command' signal from the brain. This signal is proportional to the motor effort and activates various elements of the autonomic nervous system (McClosky and Mitchell, 1972; Mitchell and Victor, 1996).

The other main idea is that sympathoexcitatory sensory receptors in the active skeletal muscles are involved in a feed-back reflex. Such receptors might be mechanically sensitive, or they might be chemosensitive and respond to substances from the active muscles. In this way, chemosensitive afferents might sense a mismatch between blood flow and metabolism in the active muscles and evoke an increase in arterial pressure to improve flow. The paper by Vissing, MacLean, Vissing, Sander, Saltin and Haller (2001) seeks to test the hypothesis that acidosis is the key factor that stimulates the chemosensitive muscle afferents. They found that muscle acidification and changes in interstitial ammonia concentration are not mediators of sympathetic activation during exercise.

In the 1930s, Alam & Smirk (1938) showed that the rise in arterial pressure associated with exercise could be augmented if the muscles were ischaemic and much of the increase in pressure (but not heart rate) could be maintained when contractions stopped but the muscle ischaemia continued. This led to the idea that metabolites stimulate muscle afferents and contribute to the rise in arterial pressure with exercise. Studies were then conducted with a patient who had unilateral sensory loss but preserved motor function in one leg. In this patient the rise in pressure was robust when the insensitive leg was contracting, but the pressor response was not maintained during post-exercise ischaemia (Alam and Smirk, 1938). This powerful 'experiment in nature' demonstrated that afferents in skeletal muscle could increase arterial pressure. It also provided evidence that central command and feedback from muscle may be redundant control mechanisms.

Later, animal experiments by (McClosky and Mitchell, 1972) confirmed that a metabolically sensitive pressor reflex originated in skeletal muscle. Subsequently, a large number of studies in animals and humans have been conducted in an effort to identify 'the' substance or substances that stimulate the afferents. Studies in anaesthetised animals indicated that while many substances can stimulate the afferents, H^+ ions appeared to be the dominant factor (Rotto, Stebbins and Kaufman, 1989).

In the 1980s, studies in humans using measurements of muscle sympathetic nerve activity (MSNA) demonstrated that while the onset of exercise was associated with an immediate rise in blood pressure and heart rate, the increase in muscle sympathetic nerve activity (MSNA) took longer to occur and could be sustained (along with the increase in arterial pressure) during post-exercise ischaemia (Mark, Victor, Nerhed and Wallin, 1985). The interpretation was that the rise in MSNA was linked to the activation of the chemosensitive afferents. Later, Victor and colleagues (1988) showed that MSNA began to rise in human volunteers during exercise when the pH in the active muscles started to fall. In patients with McArdle's disease, who lack the enzyme required to break down glycogen and do not produce lactic acid, there was no increase in MSNA during fatiguing muscle contractions (Pryor et al. 1990). This observation seemed to 'establish' muscle acidosis as the main factor that stimulates blood pressure-raising sensory afferents in contracting skeletal muscle.

However, in the study by Vissing et al. (2001), similar patients with McArdle's disease were studied, and these patients showed a rise in MSNA with contractions. These subjects performed arm flexion exercise and demonstrated a robust increase in MSNA with exercise that was sustained during post-exercise ischaemia. This rise occurred even though the muscles did not acidify. Since the studies by both Pryor et al. (1990) and Vissing et al. (2001) appear to have been carefully done, how can these observations be reconciled? Unless unappreciated differences in experimental design are responsible, the simple answer is that they cannot be reconciled. While the evidence that acidosis is a key physiological stimulator of chemosensitive afferents in muscle seems quite strong (Rotto et al., 1989), the data presented by Vissing et al. (2001) at a minimum suggest that H^+ ions are not obligatory.

Maintaining an isometric contraction at a constant force induces general reactions such as increased heart rate and blood pressure (Grucza, Kahn, Cybulski, Niewiadomski, Stupnicka and Nazar, 1989). Heart rate and blood pressure values are affected mainly by the relative force developed during the contraction (Lind and

McNicol, 1967), but other authors consider that the muscle mass engaged in the sustained contraction also has an impact on the cardiovascular response (Mitchell et al., 1980; Kjaer et al., 1991), as is the case during dynamic exercise.

Two mechanisms are involved in the cardiovascular response:

one is a reflex elicited by the stimulation of receptors in the active muscles (Alam and Smirk 1937) and mediated by type III (thinly myelinated) and IV (unmyelinated) afferents (McClosky and Mitchell, 1972). Group III afferents are more responsive to mechanical stimuli, whereas group IV afferents are stimulated by metabolites produced during the contraction, such as K^+ , lactic acid, arachidonic acid and some cyclooxygenase products such as prostaglandins and thromboxanes (Fallentin et al., 1992).

The other mechanism is a direct action of central command descending from higher motor centres on the medullary cardiovascular centres (Krogh and Lindhard, 1913; Mitchell et al., 1981). Both central and reflex peripheral mechanisms can operate simultaneously to adjust the cardiovascular response (Mitchell and Victor, 1996) and their relative contributions depend on the intensity of the contraction and therefore on the muscle fibre type recruited (Petrofsky and Lind, 1980) as well as the time elapsed from the beginning of the contraction (Kahn, Jouanin, Colomb, Huart and Monod, 1992).

In man, the maintenance of a voluntary contraction of a single muscle is impossible to realise, even at low relative force. Nevertheless, a great number of the studies related to isometric contraction in Man tend to attribute the cardiovascular response to the sole muscle under study, without taking into account the fact that one or more muscle groups can contract during the same period (co-contractions) to maintain the whole body or at least one limb in the imposed position (Jensen, Schibye, Søgaard, Simonsen and Sjøgaard, 1993).

Lind and McNicol (1967) found that when at least two muscle groups contracted simultaneously at different relative forces, the increments in heart rate and blood pressure were the same as when the muscle group, at the higher relative force, contracted separately at the force. When two or more muscles contracted at the same relative force, the resultant cardiovascular response was the same, whether they contracted separately or together. On the other hand, Mitchell et al. (1980) and Seals et al. (1983) consider that the total muscle mass engaged in a static effort plays a role in determining the cardiovascular response. Taken together, these results suggest that the amplitude of the cardiovascular response of sustained isometric contraction of a particular muscle group may be influenced by the presence of one or several concomitant contractions. Two main factors are usually responsible for the occurrence of co-contractions: the discomfort of the posture imposed and the increasing effort required to maintain the target force. The former can be significantly reduced with an appropriate posture and an adapted material, but the latter is unavoidable. Therefore, it is difficult to know to what extent the blood pressure and heart rate values recorded during a sustained isometric contraction are due to the sole muscle group under study and how much to concomitant contracting muscle groups.

The continuous and linear increase in blood pressure and heart rate during the whole handgrip contraction at 43% MVE observed in a study by Kahn, Favriou, Jouanin and Grucza (2000), since above 20% MVE there is no cardiovascular steady state in response to the local metabolic needs (Lind and McNicol, 1967; Bonde-Petersen, Henriksson and Lundin, 1975).

Muscle blood flow has an important role in the development of muscle fatigue because it alters the depletion of energy substrates and the accumulation of metabolic by-products, which ultimately affects the contractile properties of the exercising muscle (Bigland-Ritchie et al., 1995). Although skeletal muscle circulation during exercise has been studied extensively, limited studies have investigated the role of age on blood flow, capillarity and vasodilatory adjustments in humans during exercise. Relevant animal studies will therefore be cited to substantiate or provide a contrast to the human research.

Resting whole limb blood flow is reduced in healthy elderly humans compared to younger adults, and is likely due to a decrease in vascular conductance (Dinenno, Jones, Seal and Tanaka, 1999). It has been suggested that maximal blood flow during exercise is decreased with age (Degens, 1998). However, small muscle group exercise, such as handgrip, have shown no age-related difference in active muscle blood flow (Jasperse, Seal and Callister, 1994).

The possibility of an age-associated attenuation of blood flow during exercise may arise due to decreased capillarity, because muscle fibre loss and atrophy and changes in fibre type composition are expected to be accompanied by changes in muscle capillarity. Although most studies show an unchanged capillary density and a reduced capillary-to-fibre ratio in aged humans (Degens, 1998; Chilibeck, Paterson, Cunningham, Taylor and Noble, 1997) found no reduction in either capillary density or the capillary-to-fibre ratio, whereas (Coggan, Spina, King, Rogers, Brown, Nementh and Holloszy, 1992) found an age-related reduction in both measures. Because both studies examined the human gastrocnemius, it was suggested that the discrepancy may have resulted from differences in the physical activity profiles of the aged subjects in each study. Thus, the activity status of the subjects tested may influence the comparative fatigability of young and old humans with changes in capillarity, but this contribution is likely to be relatively minor.

Irrespective of age-related alterations in blood flow and related factors, the degree of blood flow occlusion that develops during an exercise task is an important parameter in muscle fatigue protocols, and could influence the comparative fatigability of young and old humans during both voluntary and electrical stimulation protocols. During intermittent electrical stimulation, an age-related slowing of contractile properties has been suggested to exacerbate the fatigability of aged humans, likely due to a prolongation of blood flow occlusion that occurs during each lengthened (slowed relaxation) tetanic contraction (Hunter et al., 1998).

Muscle blood flow occlusion is more severe during isometric than dynamic contractions, and estimates of the contraction intensity at which blood flow fails to meet the metabolic demand appears to be task-specific, largely due to the muscle size and absolute force production (Bigland-Ritchie et al., 1995). The age-related loss of muscle mass presumably alters the relationship between blood flow occlusion and contraction intensity, and may improve the relative endurance of old subjects during various fatigue tasks. For example, older subjects may be able to sustain voluntary muscle activity at a higher relative percentage of their maximal strength without the deleterious effects of blood flow occlusion on muscle fatigability, or sustain voluntary contractions at low to moderate contraction intensities for longer periods of time than young subjects. However, because muscle size and absolute force production will affect blood flow occlusion irrespective of ageing, different muscles challenged with the same fatigue task may have different endurance outcomes, and it is thus not possible to generalise that old subjects are more fatigue resistant than young subjects during relative tests of fatigability.

In conclusion, future studies should attempt to control the possible confounding effects of subject age, gender and physical activity status when comparing the fatigability of young and old humans. In addition to controlling these potential confounding factors, it appears that the fatigue task performed is very important in determining whether such characteristics as slower contractile properties and decreased muscle strength of old subjects alter muscle fatigability compared with young adults. For example, relationship between relative strength and blood flow occlusion, and age-related MU remodelling may increase the endurance capacity of old humans during voluntary protocols at low to moderate contraction intensities, whereas slowed contractile properties in the muscles of old subjects may exacerbate muscle fatigue during low frequencies of electrical stimulation. Therefore, although it is reasonable to suggest that age-related MU remodelling could decrease muscle fatigability, the variable results from the voluntary and electrically stimulated fatigue protocols do not permit a generalisation that ageing increases the relative resistance to muscle fatigue, but identify the significance of the fatigue task parameters. Despite recognising this task-dependency, a further difficulty in assessing the effect of old age on the associated fatigue mechanisms may exist because some of the age-related alterations within the neuromuscular system possibly represent adjustments that preserve function (Lexell, 1997), and there may be compensation between different potential failure sites that occur during fatigue in which the added stress on one site results in improved function at another (Bigland-Ritchie et al., 1995). The functional consequence of these alterations at the level of the whole system remains unknown.

In summary, it can be concluded from considerable gerontology research on the human neuromuscular system that, following the growth and maturation phase, maximal muscle strength levels of healthy males and females are reasonably well maintained through middle age, with some variations in the ageing effect that depend on the type of contraction. However, older adults experience an age-related sarcopenia that reduces muscle mass and strength, especially in the lower limb, which in turn leads to potential health problems such as impairments in mobility and activities of daily living, obesity, metabolic disorders and reduced aerobic capacity. The pattern of strength reduction varies according to the type of muscle contraction - greatest for concentric contractions and least for eccentric actions. Thus, older adults appear to have a relative advantage for movements in which muscles lengthen rather than shorten which is attributable to their stiffer muscle structures and prolonged crossbridge cycle of ageing myosin. Knowledge about the effects of ageing on the human neuromuscular system is required for effective prevention and treatment programs that seek to maintain high levels of physical functioning and independence in the rapidly growing population of older adults.

4.2 Comparison of characteristics between females and males

Gender differences in absolute muscle strength are well documented (Heyward, Johannes-Ellis and Romer, 1986). Studies indicate that males generally have larger and stronger muscles than females and that differences tend to be more pronounced in muscles of the upper limbs (Heyward et al., 1986), although considerable overlap has been shown to exist between the sexes (Maughan et al., 1986). Factors which affect maximum voluntary strength include cross-sectional area (CSA) of the muscle or muscle groups, specific tension (force per unit CSA, which may be affected by the fibre type distribution and the amount of non-contractile tissue present in the muscle), ability of the volunteer to fully activate the motor units and possible anatomical differences in mechanical advantage of muscles acting across a joint.

Previous studies have demonstrated that the muscle thickness and pennation angle are greater in males than in females (Kaneshia et al., 1994b; Ichinose et al., 1998). Kubo, Kanehisa and Fukunaga (2003) in their study, they investigated the gender differences in the viscoelastic properties of tendon-aponeurosis structure as well as in muscle architecture. Data from their study revealed that the females had lower stiffness and hysteresis of the tendon structures than the males.

According to Winter and Brookes (1991), the electromechanical delay in women (44.9 ms) was significantly longer than in men (39.6

ms). This observation could be attributable to a number of mechanisms. It could represent differences in fibre-type distribution (Viitasalo and Komi, 1981), type II fibres having shorter force-developing times than type I fibres. This possibility is unlikely because it has been demonstrated that systematic differences in fibre type that are attributable to gender do not occur (Nygaard, 1981).

The data in this thesis confirm earlier reports of significant gender difference in absolute strength in muscles of the upper limb. The Table 3.1.1 shows the mean grip strength of males to be 436 N whilst it is 287 N for females. The greater absolute strength of males is primarily the result of their larger muscles. Moreover, when strength was expressed relative to lean body mass, strength for males was also significantly greater (Heyward et al., 1986).

Differences between females and males were observed for certain variables. Endurance time was longer in females than in males, tables 3.2.2 to 3.2.5. Also, MF decreased to a lesser extent in females (84 Hz) than in males (86 Hz). All of these observations could be related to females having a greater proportion of type I fibres in the muscles developing grip force than males. However, there is the possibility that MVEs may not always have been produced in both sexes and this could affect the 60% MVE endurance.

EMG median frequency

Two kinds of fatiguing contractions were performed. The first was a continuous contraction. The second was an intermittent contraction.

During sustained contractions, the average of median frequency of the female and male volunteers were not significantly different in the initial 5 seconds period. Neither were the median frequencies different in females and males at the end of the contraction. The values are shown in tables 3.2.2 to 3.2.5.

One possibility is that there was some residual fatigue persisting from the first experiment. However, in the intermittent contraction the initial median frequencies were slightly higher. This suggests that recovery from the initial experiment was complete. At volitional exhaustion the median frequency was reduced to 72 (Hz) for females and 68 (Hz) for males. This was substantially higher than the median frequency just before failure in sustained contractions.

When an individual sustains an isometric contraction at a submaximal force, the typical finding is a progressive increase in the amplitude of EMG, figure 2.5 page 56, (Fuglevand et al., 1993).

The increase in EMG probably represents the cumulative activation of motor units because the discharge rates of recruited motor units remain relatively constant during sustained isometric contractions at submaximal forces (Garland, Enoka, Serrano and Robinson, 1994; Christova and Kossev, 1998). Although volunteers appear capable of recruiting motor units during such a task, the fatiguing contraction is terminated before activation of the entire motor unit pool, especially at low target forces (Fuglevand et al., 1993; West et al., 1995; Loscher, Cresswell and Thorstensson, 1996).

Endurance time

The duration of the contraction at 60% of MVE was longer in females than the males. The total duration of these intermittent contraction sequences was measured and the data are shown in tables 3.2.2 to 3.2.5 and appendix2.

The finding of greater relative endurance time in females for finger flexor at 60% MVE has also been noted by Maughan et al. (1986). Similarly, females were able to perform a greater number of repetitions with the elbow flexor muscle when lifting loads that were 50, 60 and 70% of maximum but not with loads of 80 or 90 % of maximum (Maughan et al., 1986).

The literature on muscle fatigue suggests that women generally have longer endurance times than men, especially at low-to-moderate forces (Kahn et al., 1986; Zijdewind and Kernell, 1994; West et al., 1995). Hunter and Enoka in 2001 found that the endurance time of women was greater than that for men and that endurance time was inversely related to the absolute force sustained during the contraction.

The mechanism for this difference in endurance time is unknown. A common explanation has been that males, who are usually stronger, sustain greater absolute forces when the target force is based on an individual's strength. Indirect evidence suggests that greater absolute forces are associated with increased intramuscular pressures, occlusion of blood flow, accumulation of metabolites, heightened metaboreflex responses, and impairment of oxygen delivery to the muscle (Lind and McNicol, 1967; Barnes, 1980; Sejersted et al., 1984). Furthermore, activation of the metaboreflex, as measured by rate of increase in the mean arterial pressure and heart rate (pressor response), is inversely related to endurance time. (Mitchell et al., 1983; Rowell and O'Leary, 1990).

An alternative explanation for gender difference in endurance time may relate to the work of (Haan, Rexwinkle and Doorn, 1988) , who reported that differences in muscle dimensions (i.e. muscle mass) between the sexes may be responsible for the gender difference in endurance time. These authors argue that if two muscles have similar CSA, the longer muscle will have a higher energy utilisation at the same %MVE because it has a greater number of sarcomeres in series, which will utilise energy but not enhance the force generated by the muscle. Therefore, the metabolic cost of the exercise is dependent on muscle mass rather than muscle cross sectional area alone.

A larger absolute force developed and commensurately greater muscle ATP and O_2 demand may have been associated with shorter endurance times observed for males (Maughan et al., 1986; West et al., 1995).

The findings do not identify precise mechanisms responsible for the major gender differences in muscle fatigue rate and endurance. However, the specific muscle group studied - the finger flexors - and an exercise protocol consisting of a 5 s contraction at 60% of MVE followed by 5 s of rest, permit identification of strongly tenable hypotheses. Clues to the distinctly different fatigue rate of males and females derive from the finding that a major difference in force generating capacity was established after contractions and also existed during the early part of recovery.

The faster early recovery of force generating capacity of females is an important new observation consistent with this hypothesis (Fulco, Rock, Muza and Lammi E, 1998). Virtually absent recovery of force generating capacity during muscle ischaemia applied following fatiguing exercise (Reid, 1928; Wiles and Edwards, 1982), implies that early recovery of MVE force is closely linked with muscle oxidative phosphorylation. In agreement, muscle oxygen consumption occurs primarily during recovery between intense contractions rather than during contractions (Rall, 1985) and recovery of MVE force following exhaustive quadriceps exercise is faster for endurance athletes than strength-trained athletes (Hakkinen and Myllyla, 1990).

There is large general evidence that, in addition to events originating in active muscle, processes initiated in the nervous system also may contribute to impaired performance of fatigued muscle. Recent observations (Herbert and Gandevia, 1996) challenge Merton's earlier conclusion of virtually no neural component to fatigue during voluntary contractions of the adductor pollicis muscle (Merton, 1954). These observations (Herbert and Gandevia, 1996) are consistent with the view that the gender difference observed by them also may relate in part to a difference between males and females in the degree of muscle activation. A gender difference in the extent of impairment of activation of fatigued muscle, as evidenced by a different relationship between falling muscle force and declining electromyographic activity in men vs. women (Hakkinen, 1993), may relate to a potential male-female difference in central motor drive, impaired neuromuscular propagation and/or a fall in neural excitation of muscle of reflex origin. However, the present experimental design did not include measurements to distinguish potential gender differences in impairment of muscle activation as a cause of voluntary muscle fatigue.

Half relaxation time

The first and last in a series of intermittent contractions at 60% MVE were measured. The half relaxation time of the first, last and the difference are shown in tables 3.2.2 to 3.2.5 and appendix 2. In both females and males there was a significant ($P < 0.001$) increase in half relaxation time. This indicated a physically powerful fatigue state. There was no significant difference between the mean half relaxation time in females and males at the beginning or at the end of the series of intermittent contractions. The similarity of half relaxation time between females and males found in the present study was also found by others on plantar flexors (Vandervoort and McComas, 1986) and on calf muscles (Walsh, Wright, Davies, Lin and Thompson, 1993). The half relaxation time of the twitch on triceps surae is the same in girls, boys, and young adults, which suggests a similarity and stability of fibre composition (though not size) during adolescence and early adulthood (Davies et al., 1983).

The concept of a reduced turnover of cross-bridges is supported by studies involving muscle heat production, where heat production falls as relaxation slows. It has been calculated that the reduced heat production might correspond to an approximately three-fold reduction in ATP turnover. These calculations are based on the heat produced from the splitting of phosphoryl creatine and from glycolysis (Edwards et al., 1975 a). With a reduction in relaxation rate there is a reduction in ATP and creatine phosphate, and in addition there is an accumulation of lactic acid and H^+. It has been shown in patients with myophosphorylase deficiency (MPD) that there is a slowing of relaxation with fatigue, even though these patients do not produce lactic acid, and so accumulation of lactic acid is unlikely to be a cause.

Half relaxation time cannot be simply related to hydrogen ion or lactate generation since it declines to at least as great an extent as normal when lactic acid formation is blocked either in myophosphorylase deficiency in man (Wiles, Jones and Edwards, 1981) or in iodoacetate poisoned mouse soleus (Edwards et al., 1975 a). Furthermore, the clearance of lactate from human muscle appears to follow a longer time course than recovery of half relaxation time (Sahlin, Harris and Hultman, 1975).

In conclusion, no single substrate or product of energy metabolism so far measured can simply be correlated with relaxation rates in man.

Cardiovascular system

The average systolic blood pressure of females was lower than males before contractions started. However, after both sustained and intermittent contractions there was no significant difference. There were no significant differences in diastolic pressure.

Males have consistently been found to have higher systolic and diastolic blood pressure compared with females (Cowley, Dzau, Buttrick and Cooke, 1992). Also, (Fillingim and Maixner, 1996) examined pain responses in males and females as a function of resting blood pressure and found that baseline blood pressure moderated, in part, differences between males and females in pain sensitivity. Resting systolic and diastolic blood pressure were found to correlate with thermal and ischaemic pain thresholds in the males but not in the females. In the present study, males were found to have higher blood pressure at baseline in comparison with females. blood pressure may alter pain perception (Dworkin, Elbert and Rau, 1994). Further research is needed examining the influence of baroreceptor stimulation on pain perception in males and females.

The systolic and diastolic blood pressure and their change before and after contractions are shown in tables 3.2.2 to 3.2.5 and appendix 2.

The mean female systolic BP before contractions in group 3 was significantly lower than that in males systolic BP (P = 0.0002). Systolic blood pressure significantly increased within most age group during the fatiguing contraction for both females and males. However, the mean females diastolic BP before contractions was not significantly different from males. The mean females systolic and diastolic BP after sustained and a series of intermittent contractions were not significantly different from males.

There was no significant difference in terms of heart inside the age group in both female and male.

There were no significant differences between females and males in terms of heart rates before and after the contractions (sustained and intermittent). Results are shown in tables 3.2.2 to 3.2.5.

The heart rate, unlike the blood pressure, is a function of the tension exerted by the muscle (Funderburk, Hipskind, Welton and Lind, 1974). However, there is no relationship between heart rate and muscle tension during contraction caused by external electrical stimulation (Yamamoto, Tajima, Okawa, Mizushima, Umezu and Ogata, 1999; Petrofsky, 2001). This seems to imply that central command and effort are needed to increase heart rate during fatiguing isometric contraction.

Conclusions

The greater absolute strength of males is primarily the result of their larger muscles. Females generally had longer endurance times than males. Also, median frequency decreased to a lesser extent in females than in males. All of these observations could be related to females having a greater proportion of type I fibres in the muscles developing grip force than males.

The half relaxation time is the same in girls, boys and young adults, which suggests a similarity and stability of fibre composition (though not size) during adolescence and early adulthood. These findings suggest possible uniformity of muscle function in children and adults. It is also consistent with the force generation capacity ($N.cm^2$), fatigueability, speed of contraction/relaxation and force/frequency characteristics remaining unchanged through adolescence and early adulthood.

An increase in isometric endurance in older age groups was observed and would be consistent with a relatively larger muscle volume (area) occupied by type I fibres, which are more resistant to fatigue.

It can be concluded from considerable research on the human muscular system that, following the growth and maturation phase, maximal muscle strength levels of healthy females and males are reasonably well maintained through middle age, with some variations in the aging effect that depend on the type of contraction and muscle.

These findings suggest possible differences between women and men in the adaptations of the neuromuscular system.

The results show that the systemic arterial blood pressure is sensitive to muscle performance. Previous studies demonstrated that systemic arterial pressure increases in proportion to muscle fatigue (Fitzpatrick et al., 1996; Wright et al., 1999). Sensory input about motor performance provides information concerning the adequacy of the rise in blood pressure (Wright et al., 2000). These findings have important implications for our understanding of blood pressure control during everyday activity. Motor output is very sensitive to cardiovascular responses.

In conclusion factors such as age, sex, motor unit firing rates, recruitment, motor unit synchronization and the shape of the motor unit action potentials, blood flow and intramuscular temperature all potentially change during a fatiguing contraction. The EMG signal is sensitive to all these factors. Furthermore, local motor units located in the vicinity of the recording electrodes dominate the surface EMG signal and factors such as electrode location and orientation can affect the accuracy of MFCV measurements.

Perhaps the combined effect of all these factors is too variable to allow an age related change to be detected with the sample size used in this project.

Some suggestions for further work

This study contributed further to the knowledge of muscle functions in both sexes and how it is affected by age.

This could be an important area to be investigated in different age groups. It will also be considered in different types of muscle contraction in other muscles.

Muscle function assessment in children requires significant further investigation. Although there is a wide range of procedures available, including field tests hand-held dynamometry, isokinetic dynamometry and standard weights equipment, there is limited and equivocal research on validity and reliability. Too often, adult data, procedures and equipment have been used with children of a variety of ages, with minimal consideration of the differences between children and adults.

Reduces of muscle mass and strength, in elderly especially in the lower limb, which in turn leads to potential health problems such as impairments in mobility and activities of daily living, obesity, metabolic disorders and reduced aerobic capacity. So, future studies should effort to work more on lower limb.

Knowledge about the effects of aging on the human muscular system is required for effective prevention and treatment programs that seek to maintain high levels of physical functioning and independence in the rapidly growing population of older adults.

In conclusion, future studies should attempt to control the possible confounding effects of subject age, sex and physical activity status when comparing the fatigability of young and old humans. In addition to controlling these potential confounding factors, it appears that the fatigue task performed is very important in determining whether such characteristics as slower contractile properties and decreased muscle strength of old subjects alter muscle fatigability compared with young adults. Despite recognizing this task-dependency, a further difficulty in assessing the effect of old age on the associated fatigue mechanisms may exist. Some of the age-related alterations within the neuromuscular system possibly represent adjustments that preserve function. There may be compensation between different potential failure sites that occur during fatigue in which the added stress on one site results in improved function at another. The functional consequence of these alterations at the level of the whole system remains unknown.

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APPENDICES

APPENDIX 1

Characteristics	Age group		Female	Male
Weight	1	Number	5.00	5.00
		Mean	32.60	25.60
		Median	32.00	25.00
		Mode	20.00	20.00
		Standard Error of Mean	4.82	2.06
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	48.38	47.77
		Median	47.00	44.00
		Mode	32.00	33.00
		Standard Error of Mean	2.92	2.81
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	62.78	75.33
		Median	62.00	75.00
		Mode	62.00	85.00
		Standard Error of Mean	1.75	3.23
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	62.60	80.40
		Median	63.00	80.00
		Mode	71.00	80.00
		Standard Error of Mean	3.02	5.05
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	66.60	85.90
		Median	64.50	80.00
		Mode	54.00	105.00
		Standard Error of Mean	3.71	4.79
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	60.00	86.13
		Median	59.00	87.50
		Mode	42.00	70.00
		Standard Error of Mean	5.98	4.55
		Column %	11.32	14.55
Height	1	Number	5.00	5.00
		Mean	1.31	1.30
		Median	1.29	1.35
		Mode	1.15	1.15
		Standard Error of Mean	0.05	0.05
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	1.55	1.57
		Median	1.53	1.58
		Mode	1.40	1.41
		Standard Error of Mean	0.03	0.03
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	1.69	1.78
		Median	1.68	1.79
		Mode	1.66	1.72
		Standard Error of Mean	0.03	0.02
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	1.66	1.76
		Median	1.65	1.74
		Mode	1.64	1.73
		Standard Error of Mean	0.02	0.02
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	1.62	1.79
		Median	1.63	1.79
		Mode	1.60	1.79
		Standard Error of Mean	0.02	0.03
		Column %	18.87	18.18
	6	Number	6.00	8.00

		Mean	1.64	1.82
		Median	1.65	1.83
		Mode	1.54	1.86
		Standard Error of Mean	0.03	0.03
		Column %	11.32	14.55
BMI	1	Number	5.00	5.00
		Mean	18.64	15.16
		Median	16.80	15.10
		Mode	15.10	13.70
		Standard Error of Mean	1.77	0.50
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	19.93	19.18
		Median	19.30	18.00
		Mode	17.90	15.20
		Standard Error of Mean	0.72	0.81
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	21.88	23.72
		Median	21.50	22.30
		Mode	21.00	20.10
		Standard Error of Mean	0.43	0.93
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	22.70	25.91
		Median	22.55	24.95
		Mode	21.40	23.50
		Standard Error of Mean	0.83	1.41
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	25.32	26.64
		Median	24.90	25.25
		Mode	19.80	23.10
		Standard Error of Mean	1.35	1.19
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	22.18	25.96
		Median	21.45	25.60
		Mode	21.00	22.90
		Standard Error of Mean	1.85	0.83
		Column %	11.32	14.55
Max force*	1	Number	5.00	5.00
		Mean	200.00	205.40
		Median	192.00	179.00
		Mode	90.00	130.00
		Standard Error of Mean	49.36	37.73
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	340.38	370.46
		Median	356.00	327.00
		Mode	220.00	235.00
		Standard Error of Mean	26.89	45.22
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	536.56	849.78
		Median	560.00	830.00
		Mode	343.00	900.00
		Standard Error of Mean	36.82	48.03
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	449.80	767.60
		Median	422.00	803.50
		Mode	345.00	640.00
		Standard Error of Mean	29.79	40.75
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	428.30	764.60
		Median	435.50	800.50
		Mode	306.00	550.00
		Standard Error of Mean	28.33	38.08
		Column %	18.87	18.18

	6	Number	6.00	8.00
		Mean	400.67	755.38
		Median	429.00	755.50
		Mode	429.00	517.00
		Standard Error of Mean	32.80	56.11
		Column %	11.32	14.55
Sustained duration	1	Number	5.00	5.00
		Mean	44.60	43.80
		Median	44.00	55.00
		Mode	32.00	55.00
		Standard Error of Mean	3.89	8.01
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	54.62	46.31
		Median	40.00	32.00
		Mode	40.00	25.00
		Standard Error of Mean	8.11	7.26
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	67.44	60.89
		Median	61.00	62.00
		Mode	43.00	62.00
		Standard Error of Mean	9.17	3.35
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	67.60	58.30
		Median	65.00	56.00
		Mode	32.00	56.00
		Standard Error of Mean	6.18	5.22
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	84.70	60.30
		Median	67.50	55.50
		Mode	42.00	51.00
		Standard Error of Mean	16.90	3.94
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	82.00	56.44
		Median	72.50	54.75
		Mode	49.00	36.00
		Standard Error of Mean	12.19	6.58
		Column %	11.32	14.55
IMF sustained	1	Number	5.00	5.00
		Mean	86.40	79.80
		Median	92.00	75.00
		Mode	96.00	75.00
		Standard Error of Mean	5.15	5.16
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	84.04	96.69
		Median	81.00	93.00
		Mode	72.00	73.00
		Standard Error of Mean	3.42	5.09
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	86.06	88.00
		Median	84.00	82.00
		Mode	84.00	65.00
		Standard Error of Mean	3.20	6.16
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	83.40	78.80
		Median	79.00	77.50
		Mode	77.00	61.00
		Standard Error of Mean	4.91	4.40
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	82.35	78.80
		Median	80.75	80.25
		Mode	104.00	51.00
		Standard Error of Mean	5.67	5.00

		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	86.83	89.00
		Median	87.00	82.00
		Mode	100.00	70.00
		Standard Error of Mean	6.71	7.61
		Column %	11.32	14.55
FMF sustained	1	Number	5.00	5.00
		Mean	56.80	61.20
		Median	66.00	62.00
		Mode	36.00	55.00
		Standard Error of Mean	7.18	1.69
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	49.42	64.31
		Median	43.00	67.00
		Mode	27.00	78.00
		Standard Error of Mean	4.27	7.21
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	38.06	42.22
		Median	36.00	37.00
		Mode	27.50	35.00
		Standard Error of Mean	4.13	3.94
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	43.75	40.95
		Median	34.50	34.50
		Mode	30.00	34.00
		Standard Error of Mean	7.31	6.32
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	55.63	39.44
		Median	54.50	34.60
		Mode	88.00	24.00
		Standard Error of Mean	7.61	6.30
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	49.50	49.19
		Median	35.00	42.00
		Mode	26.00	32.00
		Standard Error of Mean	11.42	6.78
		Column %	11.32	14.55
IMF-FMF sustained	1	Number	5.00	5.00
		Mean	29.60	18.60
		Median	30.00	13.00
		Mode	7.00	4.00
		Standard Error of Mean	6.86	6.84
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	34.62	32.38
		Median	33.50	37.00
		Mode	28.00	6.00
		Standard Error of Mean	3.31	5.09
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	48.00	45.78
		Median	48.00	48.00
		Mode	60.00	20.00
		Standard Error of Mean	5.34	3.97
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	39.65	37.85
		Median	41.50	37.50
		Mode	19.50	34.00
		Standard Error of Mean	3.38	3.88
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	26.47	39.36
		Median	27.00	44.50
		Mode	38.50	6.10

		Standard Error of Mean	4.24	5.42
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	37.33	39.75
		Median	37.00	35.50
		Mode	4.00	13.00
		Standard Error of Mean	8.26	7.55
		Column %	11.32	14.55
Hz/sec sustained	1	Number	5.00	5.00
		Mean	0.69	0.48
		Median	0.71	0.62
		Mode	0.14	0.07
		Standard Error of Mean	0.16	0.15
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	0.70	0.75
		Median	0.70	0.83
		Mode	0.32	0.76
		Standard Error of Mean	0.07	0.11
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	0.75	0.78
		Median	0.72	0.79
		Mode	0.35	0.29
		Standard Error of Mean	0.09	0.08
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	0.62	0.67
		Median	0.60	0.69
		Mode	0.28	0.34
		Standard Error of Mean	0.06	0.07
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	0.43	0.65
		Median	0.43	0.76
		Mode	0.11	0.12
		Standard Error of Mean	0.07	0.09
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	0.49	0.67
		Median	0.49	0.72
		Mode	0.06	0.33
		Standard Error of Mean	0.12	0.08
		Column %	11.32	14.55
Intermittent duration	1	Number	5.00	5.00
		Mean	125.00	131.00
		Median	120.00	115.00
		Mode	90.00	105.00
		Standard Error of Mean	14.14	14.78
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	157.69	168.85
		Median	130.00	110.00
		Mode	120.00	110.00
		Standard Error of Mean	20.46	28.47
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	176.11	146.22
		Median	170.00	135.00
		Mode	210.00	130.00
		Standard Error of Mean	19.94	11.39
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	215.80	163.60
		Median	230.00	177.50
		Mode	80.00	190.00
		Standard Error of Mean	33.62	15.06
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	293.00	198.50
		Median	280.00	162.50

		Mode	380.00	110.00
		Standard Error of Mean	42.62	48.64
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	301.67	180.00
		Median	265.00	165.00
		Mode	170.00	130.00
		Standard Error of Mean	60.96	18.54
		Column %	11.32	14.55
IMF intermittent	1	Number	5.00	5.00
		Mean	87.80	83.60
		Median	92.00	81.00
		Mode	67.00	75.00
		Standard Error of Mean	5.30	3.40
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	84.19	98.66
		Median	81.00	90.00
		Mode	68.00	90.00
		Standard Error of Mean	3.26	6.33
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	90.67	92.11
		Median	92.00	86.00
		Mode	92.00	84.00
		Standard Error of Mean	3.58	4.45
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	89.05	79.75
		Median	85.00	81.25
		Mode	82.00	43.00
		Standard Error of Mean	5.20	6.14
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	88.60	82.80
		Median	89.00	83.25
		Mode	64.00	53.00
		Standard Error of Mean	4.34	5.54
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	94.83	94.25
		Median	95.00	95.00
		Mode	76.00	68.00
		Standard Error of Mean	6.81	7.26
		Column %	11.32	14.55
FMF intermittent	1	Number	5.00	5.00
		Mean	67.80	70.30
		Median	74.00	70.00
		Mode	36.00	60.00
		Standard Error of Mean	8.37	3.13
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	66.50	78.65
		Median	67.00	78.00
		Mode	63.00	64.00
		Standard Error of Mean	4.13	7.30
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	76.33	72.44
		Median	78.00	70.00
		Mode	79.00	63.00
		Standard Error of Mean	3.55	3.54
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	67.85	52.70
		Median	66.75	44.85
		Mode	65.00	32.00
		Standard Error of Mean	5.97	6.62
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	74.80	59.61

		Median	74.50	62.75
		Mode	46.00	29.20
		Standard Error of Mean	5.07	5.89
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	81.42	72.94
		Median	82.50	75.00
		Mode	67.00	59.00
		Standard Error of Mean	5.50	8.08
		Column %	11.32	14.55
IMF-FMF intermittent	1	Number	5.00	5.00
		Mean	20.00	13.30
		Median	22.00	14.00
		Mode	10.00	7.00
		Standard Error of Mean	4.32	2.03
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	17.69	20.01
		Median	16.00	17.00
		Mode	16.00	5.00
		Standard Error of Mean	2.63	3.29
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	14.33	19.67
		Median	14.00	17.00
		Mode	3.00	15.00
		Standard Error of Mean	2.46	2.55
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	21.20	27.05
		Median	15.50	23.00
		Mode	13.50	8.00
		Standard Error of Mean	4.68	5.14
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	13.80	23.19
		Median	13.00	21.50
		Mode	2.00	12.00
		Standard Error of Mean	3.05	2.23
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	13.42	21.25
		Median	14.50	19.25
		Mode	3.00	9.00
		Standard Error of Mean	3.63	3.25
		Column %	11.32	14.55
Hz/sec intermittent	1	Number	5.00	5.00
		Mean	0.18	0.11
		Median	0.17	0.09
		Mode	0.06	0.06
		Standard Error of Mean	0.05	0.02
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	0.12	0.13
		Median	0.11	0.13
		Mode	0.04	0.05
		Standard Error of Mean	0.02	0.02
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	0.09	0.14
		Median	0.07	0.14
		Mode	0.01	0.07
		Standard Error of Mean	0.01	0.02
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	0.13	0.18
		Median	0.08	0.16
		Mode	0.04	0.04
		Standard Error of Mean	0.03	0.04
		Column %	18.87	18.18
	5	Number	10.00	10.00

		Mean	0.05	0.16
		Median	0.05	0.13
		Mode	0.01	0.05
		Standard Error of Mean	0.01	0.03
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	0.06	0.13
		Median	0.05	0.13
		Mode	0.01	0.05
		Standard Error of Mean	0.02	0.02
		Column %	11.32	14.55
Systolic BP before contraction	1	Number	5.00	5.00
		Mean	92.20	103.00
		Median	93.00	104.00
		Mode	71.00	85.00
		Standard Error of Mean	6.15	4.91
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	108.23	109.00
		Median	111.00	109.00
		Mode	112.00	109.00
		Standard Error of Mean	3.28	2.73
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	108.67	122.11
		Median	109.00	124.00
		Mode	109.00	131.00
		Standard Error of Mean	2.32	2.73
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	109.40	118.50
		Median	106.50	112.50
		Mode	103.00	110.00
		Standard Error of Mean	3.86	4.15
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	119.50	124.70
		Median	117.50	120.00
		Mode	106.00	120.00
		Standard Error of Mean	3.70	4.10
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	126.50	133.63
		Median	115.50	130.00
		Mode	107.00	130.00
		Standard Error of Mean	9.61	6.04
		Column %	11.32	14.55
Systolic BP after sustained	1	Number	5.00	5.00
		Mean	104.80	107.40
		Median	109.00	102.00
		Mode	86.00	125.00
		Standard Error of Mean	8.27	7.67
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	112.00	115.46
		Median	110.00	116.00
		Mode	110.00	81.00
		Standard Error of Mean	4.15	5.86
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	121.11	131.00
		Median	124.00	141.00
		Mode	98.00	96.00
		Standard Error of Mean	4.30	7.17
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	121.80	123.80
		Median	121.50	121.00
		Mode	119.00	115.00
		Standard Error of Mean	3.57	3.56
		Column %	18.87	18.18

	5	Number	10.00	10.00
		Mean	134.50	137.10
		Median	137.00	135.00
		Mode	141.00	132.00
		Standard Error of Mean	3.79	4.45
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	140.00	149.13
		Median	138.50	146.00
		Mode	115.00	127.00
		Standard Error of Mean	8.54	8.14
		Column %	11.32	14.55
Difference of systolic BP (sustained)	1	Number	5.00	5.00
		Mean	12.60	4.40
		Median	15.00	1.00
		Mode	-5.00	-4.00
		Standard Error of Mean	5.07	3.88
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	3.77	6.46
		Median	0.00	7.00
		Mode	-1.00	2.00
		Standard Error of Mean	3.48	5.97
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	12.44	8.89
		Median	9.00	16.00
		Mode	19.00	21.00
		Standard Error of Mean	3.10	7.26
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	12.40	5.30
		Median	10.00	5.00
		Mode	10.00	3.00
		Standard Error of Mean	3.19	2.13
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	15.00	12.40
		Median	11.50	11.00
		Mode	22.00	1.00
		Standard Error of Mean	4.33	2.90
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	13.50	15.50
		Median	12.50	15.00
		Mode	-5.00	4.00
		Standard Error of Mean	5.05	2.76
		Column %	11.32	14.55
Diastolic BP before contraction	1	Number	5.00	5.00
		Mean	58.80	59.20
		Median	57.00	54.00
		Mode	42.00	53.00
		Standard Error of Mean	6.76	3.81
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	70.00	63.77
		Median	70.00	67.00
		Mode	59.00	52.00
		Standard Error of Mean	3.14	2.93
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	66.33	69.89
		Median	71.00	69.00
		Mode	71.00	68.00
		Standard Error of Mean	3.00	1.95
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	74.80	73.20
		Median	74.50	71.50
		Mode	71.00	64.00
		Standard Error of Mean	1.06	2.37

		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	79.10	80.10
		Median	77.00	80.00
		Mode	76.00	80.00
		Standard Error of Mean	2.27	2.26
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	86.33	75.75
		Median	83.50	77.50
		Mode	74.00	48.00
		Standard Error of Mean	4.57	4.41
		Column %	11.32	14.55
Diastolic BP after sustained	1	Number	5.00	5.00
		Mean	64.80	64.00
		Median	53.00	61.00
		Mode	40.00	40.00
		Standard Error of Mean	11.04	9.26
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	69.00	70.92
		Median	60.00	63.00
		Mode	59.00	63.00
		Standard Error of Mean	5.02	6.13
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	68.22	66.22
		Median	65.00	63.00
		Mode	58.00	61.00
		Standard Error of Mean	3.44	3.73
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	76.10	72.90
		Median	76.00	70.50
		Mode	77.00	65.00
		Standard Error of Mean	2.47	2.40
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	76.60	78.90
		Median	81.00	78.00
		Mode	84.00	71.00
		Standard Error of Mean	4.12	2.46
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	90.00	79.00
		Median	86.50	84.00
		Mode	72.00	84.00
		Standard Error of Mean	5.70	4.27
		Column %	11.32	14.55
Difference of diastolic(sustained)	1	Number	5.00	5.00
		Mean	6.00	4.80
		Median	1.00	0.00
		Mode	-4.00	-14.00
		Standard Error of Mean	4.76	6.87
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	-1.00	7.15
		Median	-5.00	3.00
		Mode	-9.00	0.00
		Standard Error of Mean	4.80	6.17
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	1.89	-3.67
		Median	3.00	0.00
		Mode	3.00	-25.00
		Standard Error of Mean	2.84	3.71
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	1.30	-0.30
		Median	2.50	2.00
		Mode	-9.00	-12.00

		Standard Error of Mean	2.17	2.38
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	-2.50	-1.20
		Median	-1.50	-2.50
		Mode	-6.00	-3.00
		Standard Error of Mean	4.07	1.80
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	3.67	3.25
		Median	4.50	3.50
		Mode	-2.00	-5.00
		Standard Error of Mean	1.84	1.46
		Column %	11.32	14.55
HR before contraction	1	Number	5.00	5.00
		Mean	73.40	89.40
		Median	78.00	95.00
		Mode	51.00	96.00
		Standard Error of Mean	6.05	5.40
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	71.08	74.46
		Median	69.00	78.00
		Mode	64.00	79.00
		Standard Error of Mean	3.56	3.63
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	65.56	62.00
		Median	63.00	60.00
		Mode	59.00	50.00
		Standard Error of Mean	4.38	3.64
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	72.50	70.20
		Median	69.50	69.00
		Mode	65.00	62.00
		Standard Error of Mean	4.28	3.78
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	74.90	70.60
		Median	75.00	72.50
		Mode	73.00	80.00
		Standard Error of Mean	2.80	2.87
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	79.83	68.00
		Median	83.00	69.00
		Mode	51.00	48.00
		Standard Error of Mean	6.57	7.27
		Column %	11.32	14.55
HR after sustained	1	Number	5.00	5.00
		Mean	88.40	92.60
		Median	90.00	100.00
		Mode	77.00	60.00
		Standard Error of Mean	3.59	8.45
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	66.38	76.69
		Median	66.00	75.00
		Mode	59.00	65.00
		Standard Error of Mean	4.05	3.10
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	68.89	62.56
		Median	68.00	58.00
		Mode	48.00	58.00
		Standard Error of Mean	5.05	4.83
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	70.90	71.90
		Median	72.00	70.50

		Mode	49.00	72.00
		Standard Error of Mean	5.48	4.06
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	72.30	70.20
		Median	74.00	70.50
		Mode	76.00	70.00
		Standard Error of Mean	3.33	3.74
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	76.67	70.38
		Median	78.00	69.00
		Mode	49.00	54.00
		Standard Error of Mean	7.23	6.63
		Column %	11.32	14.55
Difference of HR after sustained	1	Number	5.00	5.00
		Mean	15.00	3.20
		Median	11.00	5.00
		Mode	0.00	5.00
		Standard Error of Mean	6.76	3.25
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	-4.69	2.23
		Median	-5.00	3.00
		Mode	-5.00	-7.00
		Standard Error of Mean	3.66	3.60
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	3.33	0.56
		Median	6.00	1.00
		Mode	9.00	1.00
		Standard Error of Mean	3.07	2.06
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	-1.60	1.70
		Median	-1.50	1.50
		Mode	-12.00	3.00
		Standard Error of Mean	2.04	2.13
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	-2.60	-0.40
		Median	-2.00	2.00
		Mode	-2.00	2.00
		Standard Error of Mean	2.49	2.18
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	-3.17	2.38
		Median	-1.50	1.50
		Mode	-15.00	-3.00
		Standard Error of Mean	2.61	1.48
		Column %	11.32	14.55
Sys BP after intermittent	1	Number	5.00	5.00
		Mean	121.40	107.80
		Median	118.00	106.00
		Mode	92.00	89.00
		Standard Error of Mean	11.41	8.19
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	120.85	114.69
		Median	112.00	111.00
		Mode	108.00	111.00
		Standard Error of Mean	6.79	5.51
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	121.56	129.78
		Median	120.00	130.00
		Mode	119.00	97.00
		Standard Error of Mean	4.39	6.64
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	124.10	123.80

		Median	124.00	122.50
		Mode	116.00	130.00
		Standard Error of Mean	4.92	3.59
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	128.90	139.60
		Median	124.50	134.00
		Mode	121.00	118.00
		Standard Error of Mean	4.47	5.48
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	141.50	151.00
		Median	133.50	157.00
		Mode	105.00	113.00
		Standard Error of Mean	12.22	8.66
		Column %	11.32	14.55
Difference of systolic BP (Intermittent)	1	Number	5.00	5.00
		Mean	29.20	4.80
		Median	22.00	7.00
		Mode	-1.00	-15.00
		Standard Error of Mean	13.27	5.54
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	12.62	5.69
		Median	9.00	6.00
		Mode	13.00	-16.00
		Standard Error of Mean	6.33	5.40
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	12.89	7.67
		Median	12.00	10.00
		Mode	12.00	10.00
		Standard Error of Mean	2.53	6.36
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	14.70	5.30
		Median	16.50	5.00
		Mode	15.00	0.00
		Standard Error of Mean	3.87	4.90
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	9.40	14.90
		Median	8.00	11.00
		Mode	5.00	11.00
		Standard Error of Mean	3.77	5.23
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	15.00	17.38
		Median	15.00	19.00
		Mode	-2.00	31.00
		Standard Error of Mean	4.73	5.14
		Column %	11.32	14.55
Diastolic BP after intermittent	1	Number	5.00	5.00
		Mean	82.80	66.00
		Median	78.00	64.00
		Mode	48.00	50.00
		Standard Error of Mean	16.39	8.25
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	69.31	60.38
		Median	67.00	58.00
		Mode	51.00	55.00
		Standard Error of Mean	5.19	2.93
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	65.67	65.78
		Median	66.00	62.00
		Mode	52.00	59.00
		Standard Error of Mean	3.25	3.57
		Column %	16.98	16.36
	4	Number	10.00	10.00

		Mean	71.40	73.60
		Median	68.50	73.00
		Mode	68.00	71.00
		Standard Error of Mean	2.50	2.31
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	78.60	82.60
		Median	79.50	81.00
		Mode	85.00	79.00
		Standard Error of Mean	3.64	2.64
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	86.33	89.63
		Median	83.50	85.50
		Mode	62.00	73.00
		Standard Error of Mean	6.92	6.10
		Column %	11.32	14.55
Difference of diastolic BP (intermittent)	1	Number	5.00	5.00
		Mean	24.00	6.80
		Median	16.00	4.00
		Mode	-4.00	-3.00
		Standard Error of Mean	13.41	4.97
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	-0.69	-3.38
		Median	-5.00	1.00
		Mode	-21.00	6.00
		Standard Error of Mean	4.05	3.14
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	-0.67	-4.11
		Median	1.00	-9.00
		Mode	-5.00	-12.00
		Standard Error of Mean	3.35	2.87
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	-3.40	0.40
		Median	-6.00	-1.00
		Mode	-6.00	-3.00
		Standard Error of Mean	1.94	2.35
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	-0.50	2.50
		Median	-3.00	3.00
		Mode	-7.00	-1.00
		Standard Error of Mean	3.60	2.05
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	0.00	13.88
		Median	1.00	3.00
		Mode	-12.00	3.00
		Standard Error of Mean	2.98	7.73
		Column %	11.32	14.55
HR after intermittent	1	Number	5.00	5.00
		Mean	76.40	94.80
		Median	80.00	98.00
		Mode	53.00	76.00
		Standard Error of Mean	6.35	4.81
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	77.77	78.85
		Median	78.00	78.00
		Mode	77.00	78.00
		Standard Error of Mean	3.59	3.37
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	66.44	63.67
		Median	60.00	58.00
		Mode	52.00	58.00
		Standard Error of Mean	4.71	5.51
		Column %	16.98	16.36

	4	Number	10.00	10.00
		Mean	73.80	74.80
		Median	66.00	71.00
		Mode	65.00	50.00
		Standard Error of Mean	4.96	5.00
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	72.30	68.10
		Median	72.50	69.00
		Mode	69.00	59.00
		Standard Error of Mean	3.31	3.33
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	80.17	69.63
		Median	81.50	71.50
		Mode	51.00	45.00
		Standard Error of Mean	6.91	6.95
		Column %	11.32	14.55
Difference of HR (intermittent)	1	Number	5.00	5.00
		Mean	3.00	5.40
		Median	6.00	7.00
		Mode	6.00	8.00
		Standard Error of Mean	9.44	1.44
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	6.69	4.38
		Median	6.00	1.00
		Mode	2.00	1.00
		Standard Error of Mean	3.20	2.54
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	0.89	1.67
		Median	-3.00	1.00
		Mode	-3.00	-8.00
		Standard Error of Mean	2.96	2.74
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	1.30	4.60
		Median	0.50	5.00
		Mode	-12.00	5.00
		Standard Error of Mean	2.63	3.10
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	-2.60	-2.50
		Median	-2.00	-2.50
		Mode	-4.00	2.00
		Standard Error of Mean	2.45	1.92
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	0.33	1.63
		Median	0.00	2.50
		Mode	0.00	3.00
		Standard Error of Mean	1.12	1.58
		Column %	11.32	14.55
Initial half relaxation time	1	Number	5.00	5.00
		Mean	0.09	0.09
		Median	0.08	0.08
		Mode	0.06	0.06
		Standard Error of Mean	0.02	0.01
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	0.08	0.08
		Median	0.09	0.08
		Mode	0.05	0.04
		Standard Error of Mean	0.01	0.01
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	0.09	0.09
		Median	0.09	0.10
		Mode	0.06	0.03
		Standard Error of Mean	0.01	0.01

		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	0.10	0.08
		Median	0.07	0.07
		Mode	0.06	0.04
		Standard Error of Mean	0.02	0.01
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	0.12	0.10
		Median	0.11	0.09
		Mode	0.04	0.06
		Standard Error of Mean	0.02	0.01
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	0.08	0.11
		Median	0.07	0.09
		Mode	0.05	0.06
		Standard Error of Mean	0.01	0.02
		Column %	11.32	14.55
Final half relaxation time	1	Number	5.00	5.00
		Mean	0.14	0.14
		Median	0.13	0.13
		Mode	0.08	0.08
		Standard Error of Mean	0.03	0.02
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	0.12	0.12
		Median	0.13	0.12
		Mode	0.07	0.08
		Standard Error of Mean	0.01	0.01
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	0.14	0.16
		Median	0.15	0.17
		Mode	0.09	0.09
		Standard Error of Mean	0.01	0.02
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	0.14	0.13
		Median	0.12	0.12
		Mode	0.08	0.08
		Standard Error of Mean	0.02	0.02
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	0.16	0.14
		Median	0.15	0.12
		Mode	0.07	0.08
		Standard Error of Mean	0.02	0.01
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	0.12	0.16
		Median	0.10	0.14
		Mode	0.07	0.10
		Standard Error of Mean	0.02	0.03
		Column %	11.32	14.55
Half relaxation time change	1	Number	5.00	5.00
		Mean	0.05	0.05
		Median	0.05	0.04
		Mode	0.02	0.02
		Standard Error of Mean	0.01	0.01
		Column %	9.43	9.09
	2	Number	13.00	13.00
		Mean	0.04	0.04
		Median	0.05	0.04
		Mode	0.01	0.00
		Standard Error of Mean	0.00	0.01
		Column %	24.53	23.64
	3	Number	9.00	9.00
		Mean	0.05	0.07
		Median	0.04	0.07
		Mode	0.02	0.02

		Standard Error of Mean	0.01	0.01
		Column %	16.98	16.36
	4	Number	10.00	10.00
		Mean	0.05	0.05
		Median	0.04	0.05
		Mode	0.02	0.03
		Standard Error of Mean	0.01	0.01
		Column %	18.87	18.18
	5	Number	10.00	10.00
		Mean	0.04	0.04
		Median	0.04	0.04
		Mode	0.01	0.00
		Standard Error of Mean	0.01	0.01
		Column %	18.87	18.18
	6	Number	6.00	8.00
		Mean	0.05	0.05
		Median	0.03	0.04
		Mode	0.01	0.00
		Standard Error of Mean	0.01	0.01
		Column %	11.32	14.55

Comparison between female and male				
Independent Samples Test				
	F	t	df	Sig. (2-tailed)
Age	1.818	-0.695	106.000	0.489
Weight	11.582	-3.177	106.000	0.002
Height	3.015	-3.231	106.000	0.002
BMI	4.099	-1.418	106.000	0.159
Max force[‡]	29.769	-5.738	106.000	0.000
Sustained endurance time	6.019	2.375	106.000	0.019
IMF sustained	3.476	-0.530	106.000	0.597
FMF sustained	0.076	-0.286	106.000	0.775
IMF-FMF sustained	1.588	-0.166	106.000	0.868
Hz/sec sustained	0.019	-1.247	106.000	0.215
Intermittent endurance time	7.418	2.190	106.000	0.031
IMF intermittent	2.353	-0.211	106.000	0.834
FMF intermittent	2.799	1.082	106.000	0.282
IMF-FMF intermittent	0.764	-2.250	106.000	0.027
Hz/sec intermittent	0.001	-2.521	106.000	0.013
Systolic BP before contraction	0.216	-2.594	106.000	0.011
Systolic BP after sustained	1.500	-1.432	106.000	0.155
Difference of systolic BP (sustained)	0.987	0.795	106.000	0.429
Diastolic BP before contraction	0.011	0.920	106.000	0.360
Diastolic BP after sustained	0.443	0.376	106.000	0.708
Difference of diastolic(sustained)	0.079	-0.372	106.000	0.710
HR before contraction	0.947	0.371	106.000	0.712
HR after sustained	0.006	-0.283	106.000	0.778
Difference of HR after sustained	3.110	-0.967	106.000	0.336
Sys BP after intermittent	1.165	-0.605	106.000	0.547
Difference of systolic BP (Intermittent)	0.087	1.548	106.000	0.125
Diastolic BP after intermittent	0.285	0.494	106.000	0.622
Difference of diastolic BP (intermittent)	0.614	-0.166	106.000	0.868
HR after intermittent	0.991	0.146	106.000	0.884
Difference of HR (intermittent)	1.612	-0.309	106.000	0.758
Initial half relaxation time	0.223	0.510	106.000	0.611
Final half relaxation time	0.002	-0.073	106.000	0.942
Half relaxation time change	4.793	-0.921	106.000	0.359

APPENDIX 2

Age group 1 Statistics	Sex	N	Mean	Std. Deviation	Std. Error Mean
Weight	Female	5	32.600	10.784	4.823
	Male	5	25.600	4.615	2.064
Height	Female	5	1.308	0.114	0.051
	Male	5	1.296	0.117	0.052
BMI	Female	5	18.640	3.955	1.769
	Male	5	15.160	1.113	0.498
Max force*	Female	5	200.000	110.374	49.361
	Male	5	205.400	84.364	37.729
Sustained duration	Female	5	44.600	8.706	3.894
	Male	5	43.800	17.908	8.009
IMF sustained	Female	5	86.400	11.524	5.154
	Male	5	79.800	11.541	5.161
FMF sustained	Female	5	56.800	16.053	7.179
	Male	5	61.200	3.768	1.685
IMF-FMF sustained	Female	5	29.600	15.339	6.860
	Male	5	18.600	15.291	6.838
Hz/sec sustained	Female	5	0.687	0.353	0.158
	Male	5	0.481	0.324	0.145
Intermittent duration	Female	5	125.000	31.623	14.142
	Male	5	131.000	33.053	14.782
IMF intermittent	Female	5	87.800	11.841	5.295
	Male	5	83.600	7.603	3.400
FMF intermittent	Female	5	67.800	18.714	8.369
	Male	5	70.300	6.996	3.129
IMF-FMF intermittent	Female	5	20.000	9.670	4.324
	Male	5	13.300	4.550	2.035
Hz/sec intermittent	Female	5	0.178	0.111	0.050
	Male	5	0.107	0.047	0.021
Systolic BP before contraction	Female	5	92.200	13.755	6.151
	Male	5	103.000	10.977	4.909
Systolic BP after sustained	Female	5	104.800	18.485	8.267
	Male	5	107.400	17.155	7.672
Difference of systolic BP (sustained)	Female	5	12.600	11.327	5.066
	Male	5	4.400	8.678	3.881
Diastolic BP before contraction	Female	5	58.800	15.106	6.756
	Male	5	59.200	8.526	3.813
Diastolic BP after sustained	Female	5	64.800	24.692	11.043
	Male	5	64.000	20.712	9.263
Difference of diastolic (sustained)	Female	5	6.000	10.654	4.764
	Male	5	4.800	15.353	6.866
HR before contraction	Female	5	73.400	13.539	6.055
	Male	5	89.400	12.075	5.400
HR after sustained	Female	5	88.400	8.019	3.586
	Male	5	92.600	18.889	8.447
Difference of HR after sustained	Female	5	15.000	15.116	6.760
	Male	5	3.200	7.259	3.247
Sys BP after intermittent	Female	5	121.400	25.511	11.409
	Male	5	107.800	18.308	8.188
Difference of systolic BP (Intermittent)	Female	5	29.200	29.668	13.268
	Male	5	4.800	12.377	5.535
Diastolic BP after intermittent	Female	5	82.800	36.643	16.387
	Male	5	66.000	18.439	8.246
Difference of diastolic BP (intermittent)	Female	5	24.000	29.992	13.413
	Male	5	6.800	11.122	4.974
HR after intermittent	Female	5	76.400	14.188	6.345
	Male	5	94.800	10.756	4.810
Difference of HR (intermittent)	Female	5	3.000	21.119	9.445
	Male	5	5.400	3.209	1.435
Initial half relaxation time	Female	5	0.095	0.041	0.018
	Male	5	0.088	0.024	0.011
Final half relaxation time	Female	5	0.144	0.057	0.025
	Male	5	0.138	0.046	0.021
Half relaxation time change	Female	5	0.049	0.025	0.011
	Male	5	0.049	0.032	0.014

* The unit is millivolt

IMF = Initial median frequency

FMF = Final median frequency

Independent Samples Test			
Age group 1			
	t	df	Sig. (2-tailed)
Weight	1.334	8.000	0.219
Height	0.164	8.000	0.874
BMI	1.894	8.000	0.095
Max force	-0.087	8.000	0.933
Sustained duration	0.090	8.000	0.931
IMF sustained	0.905	8.000	0.392
FMF sustained	-0.597	8.000	0.567
IMF-FMF sustained	1.136	8.000	0.289
Hz/sec sustained	0.961	8.000	0.365
Intermittent duration	-0.293	8.000	0.777
IMF intermittent	0.667	8.000	0.523
FMF intermittent	-0.280	8.000	0.787
IMF-FMF intermittent	1.402	8.000	0.199
Hz/sec intermittent	1.321	8.000	0.223
Systolic BP before contraction	-1.372	8.000	0.207
Systolic BP after sustained	-0.231	8.000	0.823
Difference of systolic BP (sustained)	1.285	8.000	0.235
Diastolic BP before contraction	-0.052	8.000	0.960
Diastolic BP after sustained	0.056	8.000	0.957
Difference of diastolic (sustained)	0.144	8.000	0.889
HR before contraction	-1.972	8.000	0.084
HR after sustained	-0.458	8.000	0.659
Difference of HR after sustained	1.573	8.000	0.154
Sys BP after intermittent	0.968	8.000	0.361
Difference of systolic BP (Intermittent)	1.697	8.000	0.128
Diastolic BP after intermittent	0.916	8.000	0.387
Difference of diastolic BP (intermittent)	1.202	8.000	0.264
HR after intermittent	-2.311	8.000	0.050
Difference of HR (intermittent)	-0.251	8.000	0.808
Initial half relaxation time	0.305	8.000	0.768
Final half relaxation time	0.180	8.000	0.861
Half relaxation time change	-0.034	8.000	0.974

IMF = Initial median frequency
FMF = Final median frequency

Age group 2 Statistics	Sex	N	Mean	Std. Deviation	Std. Error Mean
Weight	Female	13	48.385	10.540	2.923
	Male	13	47.769	10.117	2.806
Height	Female	13	1.549	0.095	0.026
	Male	13	1.572	0.094	0.026
BMI	Female	13	19.931	2.595	0.720
	Male	13	19.177	2.913	0.808
Max force*	Female	13	340.385	96.958	26.891
	Male	13	370.462	163.028	45.216
Sustained duration	Female	13	54.615	29.233	8.108
	Male	13	46.308	26.186	7.263
IMF sustained	Female	13	84.038	12.331	3.420
	Male	13	96.692	18.341	5.087
FMF sustained	Female	13	49.423	15.399	4.271
	Male	13	64.308	26.004	7.212
IMF-FMF sustained	Female	13	34.615	11.932	3.309
	Male	13	32.385	18.343	5.087
Hz/sec sustained	Female	13	0.701	0.252	0.070
	Male	13	0.750	0.403	0.112
Intermittent duration	Female	13	157.692	73.757	20.456
	Male	13	168.846	102.655	28.471
IMF intermittent	Female	13	84.192	11.738	3.255
	Male	13	98.662	22.821	6.329
FMF intermittent	Female	13	66.500	14.891	4.130
	Male	13	78.654	26.304	7.295
IMF-FMF intermittent	Female	13	17.692	9.499	2.635
	Male	13	20.008	11.857	3.288
Hz/sec intermittent	Female	13	0.125	0.074	0.020
	Male	13	0.128	0.056	0.016
Systolic BP before contraction	Female	13	108.231	11.826	3.280
	Male	13	109.000	9.857	2.734
Systolic BP after sustained	Female	13	112.000	14.961	4.149
	Male	13	115.462	21.133	5.861
Difference of systolic BP (sustained)	Female	13	3.769	12.558	3.483
	Male	13	6.462	21.524	5.970
Diastolic BP before contraction	Female	13	70.000	11.321	3.140
	Male	13	63.769	10.561	2.929
Diastolic BP after sustained	Female	13	69.000	18.102	5.020
	Male	13	70.923	22.104	6.130
Difference of diastolic (sustained)	Female	13	-1.000	17.311	4.801
	Male	13	7.154	22.233	6.166
HR before contraction	Female	13	71.077	12.842	3.562
	Male	13	74.462	13.087	3.630
HR after sustained	Female	13	66.385	14.598	4.049
	Male	13	76.692	11.161	3.095
Difference of HR after sustained	Female	13	-4.692	13.212	3.664
	Male	13	2.231	12.962	3.595
Sys BP after intermittent	Female	13	120.846	24.474	6.788
	Male	13	114.692	19.851	5.506
Difference of systolic BP (Intermittent)	Female	13	12.615	22.838	6.334
	Male	13	5.692	19.482	5.403
Diastolic BP after intermittent	Female	13	69.308	18.697	5.186
	Male	13	60.385	10.556	2.928
Difference of diastolic BP (intermittent)	Female	13	-0.692	14.620	4.055
	Male	13	-3.385	11.318	3.139
HR after intermittent	Female	13	77.769	12.930	3.586
	Male	13	78.846	12.144	3.368
Difference of HR (intermittent)	Female	13	6.692	11.535	3.199
	Male	13	4.385	9.170	2.543
Initial half relaxation time	Female	13	0.083	0.021	0.006
	Male	13	0.085	0.035	0.010
Final half relaxation time	Female	13	0.124	0.028	0.008
	Male	13	0.123	0.036	0.010
Half relaxation time change	Female	13	0.040	0.017	0.005
	Male	13	0.038	0.034	0.009

* The unit is milli volt

IMF = Initial median frequency

FMF = Final median frequency

Independent Samples Test			
Age group 2			
	t	df	Sig. (2-tailed)
Weight	0.152	24.000	0.881
Height	-0.623	24.000	0.539
BMI	0.697	24.000	0.493
Max force	-0.572	24.000	0.573
Sustained duration	0.763	24.000	0.453
IMF sustained	-2.064	24.000	0.050
FMF sustained	-1.776	24.000	0.088
IMF-FMF sustained	0.368	24.000	0.716
Hz/sec sustained	-0.371	24.000	0.714
Intermittent duration	-0.318	24.000	0.753
IMF intermittent	-2.033	24.000	0.053
FMF intermittent	-1.450	24.000	0.160
IMF-FMF intermittent	-0.549	24.000	0.588
Hz/sec intermittent	-0.111	24.000	0.913
Systolic BP before contraction	-0.180	24.000	0.859
Systolic BP after sustained	-0.482	24.000	0.634
Difference of systolic BP (sustained)	-0.390	24.000	0.700
Diastolic BP before contraction	1.451	24.000	0.160
Diastolic BP after sustained	-0.243	24.000	0.810
Difference of diastolic (sustained)	-1.043	24.000	0.307
HR before contraction	-0.666	24.000	0.512
HR after sustained	-2.023	24.000	0.054
Difference of HR after sustained	-1.349	24.000	0.190
Sys BP after intermittent	0.704	24.000	0.488
Difference of systolic BP (Intermittent)	0.832	24.000	0.414
Diastolic BP after intermittent	1.498	24.000	0.147
Difference of diastolic BP (intermittent)	0.525	24.000	0.604
HR after intermittent	-0.219	24.000	0.829
Difference of HR (intermittent)	0.565	24.000	0.578
Initial half relaxation time	-0.125	24.000	0.902
Final half relaxation time	0.085	24.000	0.933
Half relaxation time change	0.235	24.000	0.816

IMF = Initial median frequency
FMF = Final median frequency

Age group 3 Statistics					
	Sex	N	Mean	Std. Deviation	Std. Error Mean
Weight	Female	9	62.778	5.263	1.754
	Male	9	75.333	9.682	3.227
Height	Female	9	1.694	0.081	0.027
	Male	9	1.781	0.048	0.016
BMI	Female	9	21.878	1.278	0.426
	Male	9	23.722	2.789	0.930
Max force*	Female	9	536.556	110.454	36.818
	Male	9	849.778	144.098	48.033
Sustained duration	Female	9	67.444	27.514	9.171
	Male	9	60.889	10.043	3.348
IMF sustained	Female	9	86.056	9.593	3.198
	Male	9	88.000	18.486	6.162
FMF sustained	Female	9	38.056	12.375	4.125
	Male	9	42.222	11.832	3.944
IMF-FMF sustained	Female	9	48.000	16.008	5.336
	Male	9	45.778	11.922	3.974
Hz/sec sustained	Female	9	0.754	0.275	0.092
	Male	9	0.777	0.247	0.082
Intermittent duration	Female	9	176.111	59.832	19.944
	Male	9	146.222	34.164	11.388
IMF intermittent	Female	9	90.667	10.735	3.578
	Male	9	92.111	13.348	4.449
FMF Intermittent	Female	9	76.333	10.654	3.551
	Male	9	72.444	10.608	3.536
IMF-FMF intermittent	Female	9	14.333	7.365	2.455
	Male	9	19.667	7.653	2.551
Hz/sec intermittent	Female	9	0.089	0.044	0.015
	Male	9	0.140	0.060	0.020
Systolic BP before contraction	Female	9	108.667	6.964	2.321
	Male	9	122.111	8.192	2.731
Systolic BP after sustained	Female	9	121.111	12.898	4.299
	Male	9	131.000	21.517	7.172
Difference of systolic BP (sustained)	Female	9	12.444	9.302	3.101
	Male	9	8.889	21.780	7.260
Diastolic BP before contraction	Female	9	66.333	9.000	3.000
	Male	9	69.889	5.840	1.947
Diastolic BP after sustained	Female	9	68.222	10.317	3.439
	Male	9	66.222	11.200	3.733
Difference of diastolic (sustained)	Female	9	1.889	8.507	2.836
	Male	9	-3.667	11.136	3.712
HR before contraction	Female	9	65.556	13.154	4.385
	Male	9	62.000	10.920	3.640
HR after sustained	Female	9	68.889	15.161	5.054
	Male	9	62.556	14.501	4.834
Difference of HR after sustained	Female	9	3.333	9.206	3.069
	Male	9	0.556	6.167	2.056
Sys BP after intermittent	Female	9	121.556	13.182	4.394
	Male	9	129.778	19.917	6.639
Difference of systolic BP (Intermittent)	Female	9	12.889	7.590	2.530
	Male	9	7.667	19.066	6.355
Diastolic BP after intermittent	Female	9	65.667	9.760	3.253
	Male	9	65.778	10.710	3.570
Difference of diastolic BP (intermittent)	Female	9	-0.667	10.062	3.354
	Male	9	-4.111	8.609	2.870
HR after intermittent	Female	9	66.444	14.117	4.706
	Male	9	63.667	16.530	5.510
Difference of HR (intermittent)	Female	9	0.889	8.894	2.965
	Male	9	1.667	8.231	2.744
Initial half relaxation time	Female	9	0.093	0.026	0.009
	Male	9	0.094	0.036	0.012
Final half relaxation time	Female	9	0.144	0.026	0.009
	Male	9	0.163	0.045	0.015
Half relaxation time change	Female	9	0.051	0.023	0.008
	Male	9	0.069	0.033	0.011

* The unit is milli volt

IMF = Initial median frequency

FMF = Final median frequency

Independent Samples Test			
Age group 3			
	t	df	Sig. (2-tailed)
Weight	-3.418	16.000	0.004
Height	-2.758	16.000	0.014
BMI	-1.804	16.000	0.090
Max force	-5.176	16.000	0.000
Sustained duration	0.671	16.000	0.512
IMF sustained	-0.280	16.000	0.783
FMF sustained	-0.730	16.000	0.476
IMF-FMF sustained	0.334	16.000	0.743
Hz/sec sustained	-0.186	16.000	0.855
Intermittent duration	1.301	16.000	0.212
IMF intermittent	-0.253	16.000	0.804
FMF intermittent	0.776	16.000	0.449
IMF-FMF intermittent	-1.506	16.000	0.151
Hz/sec intermittent	-2.054	16.000	0.057
Systolic BP before contraction	-3.751	16.000	0.002
Systolic BP after sustained	-1.183	16.000	0.254
Difference of systolic BP (sustained)	0.450	16.000	0.658
Diastolic BP before contraction	-0.994	16.000	0.335
Diastolic BP after sustained	0.394	16.000	0.699
Difference of diastolic (sustained)	1.189	16.000	0.252
HR before contraction	0.624	16.000	0.541
HR after sustained	0.906	16.000	0.379
Difference of HR after sustained	0.752	16.000	0.463
Sys BP after intermittent	-1.033	16.000	0.317
Difference of systolic BP (Intermittent)	0.763	16.000	0.456
Diastolic BP after intermittent	-0.023	16.000	0.982
Difference of diastolic BP (intermittent)	0.780	16.000	0.447
HR after intermittent	0.383	16.000	0.706
Difference of HR (intermittent)	-0.193	16.000	0.850
Initial half relaxation time	-0.084	16.000	0.934
Final half relaxation time	-1.059	16.000	0.305
Half relaxation time change	-1.290	16.000	0.215

IMF = Initial median frequency
FMF = Final median frequency

Age group 4 Statistics					
	Sex	N	Mean	Std. Deviation	Std. Error Mean
Weight	Female	10	62.600	9.559	3.023
	Male	10	80.400	15.960	5.047
Height	Female	10	1.658	0.053	0.017
	Male	10	1.759	0.061	0.019
BMI	Female	10	22.700	2.612	0.826
	Male	10	25.910	4.464	1.411
Max force*	Female	10	449.800	94.212	29.793
	Male	10	767.600	128.868	40.752
Sustained duration	Female	10	67.600	19.552	6.183
	Male	10	58.300	16.499	5.218
IMF sustained	Female	10	83.400	15.529	4.911
	Male	10	78.800	13.919	4.402
FMF sustained	Female	10	43.750	23.132	7.315
	Male	10	40.950	19.990	6.321
IMF-FMF sustained	Female	10	39.650	10.698	3.383
	Male	10	37.850	12.257	3.876
Hz/sec sustained	Female	10	0.621	0.204	0.065
	Male	10	0.671	0.212	0.067
Intermittent duration	Female	10	215.800	106.321	33.622
	Male	10	163.600	47.629	15.062
IMF intermittent	Female	10	89.050	16.432	5.196
	Male	10	79.750	19.421	6.142
FMF intermittent	Female	10	67.850	18.870	5.967
	Male	10	52.700	20.938	6.621
IMF-FMF intermittent	Female	10	21.200	14.808	4.683
	Male	10	27.050	16.249	5.138
Hz/sec intermittent	Female	10	0.128	0.107	0.034
	Male	10	0.185	0.137	0.043
Systolic BP before contraction	Female	10	109.400	12.213	3.862
	Male	10	118.500	13.125	4.151
Systolic BP after sustained	Female	10	121.800	11.302	3.574
	Male	10	123.800	11.243	3.555
Difference of systolic BP (sustained)	Female	10	12.400	10.080	3.187
	Male	10	5.300	6.734	2.129
Diastolic BP before contraction	Female	10	74.800	3.360	1.062
	Male	10	73.200	7.480	2.365
Diastolic BP after sustained	Female	10	76.100	7.795	2.465
	Male	10	72.900	7.578	2.397
Difference of diastolic (sustained)	Female	10	1.300	6.865	2.171
	Male	10	-0.300	7.514	2.376
HR before contraction	Female	10	72.500	13.542	4.282
	Male	10	70.200	11.952	3.779
HR after sustained	Female	10	70.900	17.330	5.480
	Male	10	71.900	12.827	4.056
Difference of HR after sustained	Female	10	-1.600	6.450	2.040
	Male	10	1.700	6.750	2.135
Sys BP after intermittent	Female	10	124.100	15.567	4.923
	Male	10	123.800	11.351	3.589
Difference of systolic BP (Intermittent)	Female	10	14.700	12.239	3.870
	Male	10	5.300	15.492	4.899
Diastolic BP after intermittent	Female	10	71.400	7.891	2.495
	Male	10	73.600	7.306	2.310
Difference of diastolic BP (intermittent)	Female	10	-3.400	6.132	1.939
	Male	10	0.400	7.427	2.349
HR after intermittent	Female	10	73.800	15.683	4.959
	Male	10	74.800	15.817	5.002
Difference of HR (intermittent)	Female	10	1.300	8.314	2.629
	Male	10	4.600	9.789	3.096
Initial half relaxation time	Female	10	0.096	0.059	0.019
	Male	10	0.081	0.036	0.011
Final half relaxation time	Female	10	0.143	0.074	0.024
	Male	10	0.132	0.052	0.017
Half relaxation time change	Female	10	0.047	0.024	0.008
	Male	10	0.051	0.022	0.007

* The unit is milli volt

IMF = Initial median frequency

FMF = Final median frequency

Independent Samples Test Age group 4	t	df	Sig. (2-tailed)
Weight	-3.026	18.000	0.007
Height	-3.930	18.000	0.001
BMI	-1.963	18.000	0.065
Max force	-6.295	18.000	0.000
Sustained duration	1.150	18.000	0.265
IMF sustained	0.698	18.000	0.494
FMF sustained	0.290	18.000	0.775
IMF-FMF sustained	0.350	18.000	0.730
Hz/sec sustained	-0.529	18.000	0.603
Intermittent duration	1.417	18.000	0.174
IMF intermittent	1.156	18.000	0.263
FMF intermittent	1.700	18.000	0.106
IMF-FMF intermittent	-0.841	18.000	0.411
Hz/sec intermittent	-1.036	18.000	0.314
Systolic BP before contraction	-1.605	18.000	0.126
Systolic BP after sustained	-0.397	18.000	0.696
Difference of systolic BP (sustained)	1.852	18.000	0.080
Diastolic BP before contraction	0.617	18.000	0.545
Diastolic BP after sustained	0.931	18.000	0.364
Difference of diastolic (sustained)	0.497	18.000	0.625
HR before contraction	0.403	18.000	0.692
HR after sustained	-0.147	18.000	0.885
Difference of HR after sustained	-1.118	18.000	0.278
Sys BP after intermittent	0.049	18.000	0.961
Difference of systolic BP (Intermittent)	1.506	18.000	0.150
Diastolic BP after intermittent	-0.647	18.000	0.526
Difference of diastolic BP (intermittent)	-1.248	18.000	0.228
HR after intermittent	-0.142	18.000	0.889
Difference of HR (intermittent)	-0.813	18.000	0.427
Initial half relaxation time	0.671	18.000	0.511
Final half relaxation time	0.385	18.000	0.705
Half relaxation time change	-0.354	18.000	0.727

IMF = Initial median frequency
FMF = Final median frequency

Age group 5 Statistics					
	Sex	N	Mean	Std. Deviation	Std. Error Mean
Weight	Female	10	66.600	11.721	3.706
	Male	10	85.900	15.132	4.785
Height	Female	10	1.622	0.057	0.018
	Male	10	1.793	0.079	0.025
BMI	Female	10	25.320	4.269	1.350
	Male	10	26.640	3.772	1.193
Max force*	Female	10	428.300	89.594	28.332
	Male	10	764.600	120.404	38.075
Sustained duration	Female	10	84.700	53.431	16.896
	Male	10	60.300	12.455	3.939
IMF sustained	Female	10	82.350	17.944	5.675
	Male	10	78.804	15.796	4.995
FMF sustained	Female	10	55.630	24.050	7.605
	Male	10	39.440	19.928	6.302
IMF-FMF sustained	Female	10	26.470	13.401	4.238
	Male	10	39.364	17.132	5.418
Hz/sec sustained	Female	10	0.428	0.207	0.065
	Male	10	0.655	0.280	0.089
Intermittent duration	Female	10	293.000	134.767	42.617
	Male	10	198.500	153.805	48.637
IMF intermittent	Female	10	88.600	13.721	4.339
	Male	10	82.800	17.515	5.539
FMF intermittent	Female	10	74.800	16.047	5.075
	Male	10	59.610	18.627	5.890
IMF-FMF intermittent	Female	10	13.800	9.659	3.054
	Male	10	23.190	7.040	2.226
Hz/sec intermittent	Female	10	0.052	0.036	0.011
	Male	10	0.155	0.088	0.028
Systolic BP before contraction	Female	10	119.500	11.702	3.701
	Male	10	124.700	12.962	4.099
Systolic BP after sustained	Female	10	134.500	11.984	3.790
	Male	10	137.100	14.075	4.451
Difference of systolic BP (sustained)	Female	10	15.000	13.679	4.326
	Male	10	12.400	9.180	2.903
Diastolic BP before contraction	Female	10	79.100	7.187	2.273
	Male	10	80.100	7.141	2.258
Diastolic BP after sustained	Female	10	76.600	13.015	4.116
	Male	10	78.900	7.781	2.461
Difference of diastolic (sustained)	Female	10	-2.500	12.886	4.075
	Male	10	-1.200	5.692	1.800
HR before contraction	Female	10	74.900	8.863	2.803
	Male	10	70.600	9.070	2.868
HR after sustained	Female	10	72.300	10.520	3.327
	Male	10	70.200	11.811	3.735
Difference of HR after sustained	Female	10	-2.600	7.877	2.491
	Male	10	-0.400	6.899	2.182
Sys BP after intermittent	Female	10	128.900	14.138	4.471
	Male	10	139.600	17.322	5.478
Difference of systolic BP (Intermittent)	Female	10	9.400	11.928	3.772
	Male	10	14.900	16.536	5.229
Diastolic BP after intermittent	Female	10	78.600	11.520	3.643
	Male	10	82.600	8.343	2.638
Difference of diastolic BP (intermittent)	Female	10	-0.500	11.394	3.603
	Male	10	2.500	6.468	2.045
HR after intermittent	Female	10	72.300	10.478	3.313
	Male	10	68.100	10.546	3.335
Difference of HR (intermittent)	Female	10	-2.600	7.763	2.455
	Male	10	-2.500	6.060	1.916
Initial half relaxation time	Female	10	0.124	0.062	0.020
	Male	10	0.095	0.035	0.011
Final half relaxation time	Female	10	0.163	0.070	0.022
	Male	10	0.138	0.047	0.015
Half relaxation time change	Female	10	0.038	0.018	0.006
	Male	10	0.043	0.026	0.008

* The unit is milli volt

IMF = Initial median frequency

FMF = Final median frequency

Independent Samples Test			
Age group 5			
	t	df	Sig. (2-tailed)
Weight	-3.189	18.000	0.005
Height	-5.546	18.000	0.000
BMI	-0.733	18.000	0.473
Max force	-7.086	18.000	0.000
Sustained duration	1.406	18.000	0.177
IMF sustained	0.469	18.000	0.645
FMF sustained	1.639	18.000	0.119
IMF-FMF sustained	-1.875	18.000	0.077
Hz/sec sustained	-2.056	18.000	0.055
Intermittent duration	1.461	18.000	0.161
IMF intermittent	0.824	18.000	0.421
FMF intermittent	1.954	18.000	0.066
IMF-FMF intermittent	-2.484	18.000	0.023
Hz/sec intermittent	-3.452	18.000	0.003
Systolic BP before contraction	-0.942	18.000	0.359
Systolic BP after sustained	-0.445	18.000	0.662
Difference of systolic BP (sustained)	0.499	18.000	0.624
Diastolic BP before contraction	-0.312	18.000	0.759
Diastolic BP after sustained	-0.480	18.000	0.637
Difference of diastolic (sustained)	-0.292	18.000	0.774
HR before contraction	1.072	18.000	0.298
HR after sustained	0.420	18.000	0.680
Difference of HR after sustained	-0.664	18.000	0.515
Sys BP after intermittent	-1.513	18.000	0.148
Difference of systolic BP (Intermittent)	-0.853	18.000	0.405
Diastolic BP after intermittent	-0.889	18.000	0.386
Difference of diastolic BP (intermittent)	-0.724	18.000	0.478
HR after intermittent	0.893	18.000	0.383
Difference of HR (intermittent)	-0.032	18.000	0.975
Initial half relaxation time	1.299	18.000	0.210
Final half relaxation time	0.923	18.000	0.368
Half relaxation time change	-0.453	18.000	0.656

IMF = Initial median frequency
FMF = Final median frequency

Age group 6 Statistics					
	Sex	N	Mean	Std. Deviation	Std. Error Mean
Weight	Female	6	60.000	14.642	5.978
	Male	8	86.125	12.867	4.549
Height	Female	6	1.640	0.062	0.025
	Male	8	1.818	0.073	0.026
BMI	Female	6	22.183	4.525	1.847
	Male	8	25.963	2.344	0.829
Max force*	Female	6	400.667	80.343	32.800
	Male	8	755.375	158.699	56.109
Sustained duration	Female	6	82.000	29.853	12.187
	Male	8	56.438	18.608	6.579
IMF sustained	Female	6	86.833	16.437	6.710
	Male	8	89.000	21.534	7.613
FMF sustained	Female	6	49.500	27.984	11.424
	Male	8	49.188	19.168	6.777
IMF-FMF sustained	Female	6	37.333	20.235	8.261
	Male	8	39.750	21.354	7.550
Hz/sec sustained	Female	6	0.489	0.306	0.125
	Male	8	0.667	0.227	0.080
Intermittent duration	Female	6	301.667	149.321	60.960
	Male	8	180.000	52.440	18.540
IMF intermittent	Female	6	94.833	16.678	6.809
	Male	8	94.250	20.541	7.262
FMF intermittent	Female	6	81.417	13.463	5.496
	Male	8	72.938	22.842	8.076
IMF-FMF intermittent	Female	6	13.417	8.902	3.634
	Male	8	21.250	9.189	3.249
Hz/sec intermittent	Female	6	0.060	0.054	0.022
	Male	8	0.127	0.068	0.024
Systolic BP before contraction	Female	6	126.500	23.535	9.608
	Male	8	133.625	17.096	6.044
Systolic BP after sustained	Female	6	140.000	20.919	8.540
	Male	8	149.125	23.031	8.143
Difference of systolic BP (sustained)	Female	6	13.500	12.373	5.051
	Male	8	15.500	7.801	2.758
Diastolic BP before contraction	Female	6	86.333	11.183	4.566
	Male	8	75.750	12.464	4.407
Diastolic BP after sustained	Female	6	90.000	13.957	5.698
	Male	8	79.000	12.083	4.272
Difference of diastolic (sustained)	Female	6	3.667	4.502	1.838
	Male	8	3.250	4.132	1.461
HR before contraction	Female	6	79.833	16.092	6.570
	Male	8	68.000	20.563	7.270
HR after sustained	Female	6	76.667	17.716	7.233
	Male	8	70.375	18.738	6.625
Difference of HR after sustained	Female	6	-3.167	6.401	2.613
	Male	8	2.375	4.173	1.475
Sys BP after intermittent	Female	6	141.500	29.938	12.222
	Male	8	151.000	24.489	8.658
Difference of systolic BP (Intermittent)	Female	6	15.000	11.593	4.733
	Male	8	17.375	14.550	5.144
Diastolic BP after intermittent	Female	6	86.333	16.955	6.922
	Male	8	89.625	17.262	6.103
Difference of diastolic BP (intermittent)	Female	6	0.000	7.294	2.978
	Male	8	13.875	21.873	7.733
HR after intermittent	Female	6	80.167	16.916	6.906
	Male	8	69.625	19.654	6.949
Difference of HR (intermittent)	Female	6	0.333	2.733	1.116
	Male	8	1.625	4.470	1.580
Initial half relaxation time	Female	6	0.078	0.033	0.014
	Male	8	0.110	0.056	0.020
Final half relaxation time	Female	6	0.123	0.056	0.023
	Male	8	0.162	0.075	0.027
Half relaxation time change	Female	6	0.045	0.032	0.013
	Male	8	0.052	0.036	0.013

* The unit is milli volt

IMF = Initial median frequency

FMF = Final median frequency

Independent Samples Test			
Age group 6			
	t	df	Sig. (2-tailed)
Weight	-3.548	12.000	0.004
Height	-4.796	12.000	0.000
BMI	-2.043	12.000	0.064
Max force	-4.982	12.000	0.000
Sustained duration	1.977	12.000	0.072
IMF sustained	-0.205	12.000	0.841
FMF sustained	0.025	12.000	0.981
IMF-FMF sustained	-0.214	12.000	0.834
Hz/sec sustained	-1.260	12.000	0.231
Intermittent duration	2.158	12.000	0.052
IMF intermittent	0.057	12.000	0.956
FMF intermittent	0.806	12.000	0.436
IMF-FMF intermittent	-1.599	12.000	0.136
Hz/sec intermittent	-1.986	12.000	0.070
Systolic BP before contraction	-0.659	12.000	0.523
Systolic BP after sustained	-0.762	12.000	0.461
Difference of systolic BP (sustained)	-0.372	12.000	0.717
Diastolic BP before contraction	1.640	12.000	0.127
Diastolic BP after sustained	1.579	12.000	0.140
Difference of diastolic (sustained)	0.180	12.000	0.860
HR before contraction	1.164	12.000	0.267
HR after sustained	0.636	12.000	0.537
Difference of HR after sustained	-1.967	12.000	0.073
Sys BP after intermittent	-0.654	12.000	0.525
Difference of systolic BP (Intermittent)	-0.328	12.000	0.748
Diastolic BP after intermittent	-0.356	12.000	0.728
Difference of diastolic BP (intermittent)	-1.480	12.000	0.165
HR after intermittent	1.052	12.000	0.314
Difference of HR (intermittent)	-0.622	12.000	0.545
Initial half relaxation time	-1.236	12.000	0.240
Final half relaxation time	-1.057	12.000	0.311
Half relaxation time change	-0.358	12.000	0.727

IMF = Initial median frequency
FMF = Final median frequency

APPENDIX 3

Multiple Comparisons					
Tukey HSD					
			Mean Difference	Std. Error	Sig.
Dependent Variable	Age group	Age group			
Weight	1	2	-18.977	5.125	0.005
		3	-39.956	5.432	0.000
		4	-42.400	5.334	0.000
		5	-47.150	5.334	0.000
		6	-45.829	5.702	0.000
	2	1	18.977	5.125	0.005
		3	-20.979	4.223	0.000
		4	-23.423	4.096	0.000
		5	-28.173	4.096	0.000
		6	-26.852	4.566	0.000
	3	1	39.956	5.432	0.000
		2	20.979	4.223	0.000
		4	-2.444	4.475	0.994
		5	-7.194	4.475	0.595
		6	-5.873	4.908	0.838
	4	1	42.400	5.334	0.000
		2	23.423	4.096	0.000
		3	2.444	4.475	0.994
		5	-4.750	4.355	0.884
		6	-3.429	4.799	0.980
	5	1	47.150	5.334	0.000
		2	28.173	4.096	0.000
		3	7.194	4.475	0.595
		4	4.750	4.355	0.884
		6	1.321	4.799	1.000
	6	1	45.829	5.702	0.000
		2	26.852	4.566	0.000
		3	5.873	4.908	0.838
		4	3.429	4.799	0.980
		5	-1.321	4.799	1.000
Height	1	2	-0.259	0.036	0.000
		3	-0.436	0.038	0.000
		4	-0.407	0.037	0.000
		5	-0.406	0.037	0.000
		6	-0.439	0.040	0.000
	2	1	0.259	0.036	0.000
		3	-0.177	0.029	0.000
		4	-0.148	0.029	0.000
		5	-0.147	0.029	0.000
		6	-0.181	0.032	0.000
	3	1	0.436	0.038	0.000
		2	0.177	0.029	0.000
		4	0.029	0.031	0.935
		5	0.030	0.031	0.926
		6	-0.004	0.034	1.000
	4	1	0.407	0.037	0.000
		2	0.148	0.029	0.000
		3	-0.029	0.031	0.935
		5	0.001	0.030	1.000
		6	-0.033	0.033	0.921
	5	1	0.406	0.037	0.000
		2	0.147	0.029	0.000
		3	-0.030	0.031	0.926
		4	-0.001	0.030	1.000
		6	-0.034	0.033	0.912
	6	1	0.439	0.040	0.000
		2	0.181	0.032	0.000
		3	0.004	0.034	1.000
		4	0.033	0.033	0.921
		5	0.034	0.033	0.912
BMI	1	2	-2.654	1.254	0.287
		3	-5.900	1.329	0.000
		4	-7.405	1.305	0.000
		5	-9.080	1.305	0.000
		6	-7.443	1.395	0.000
	2	1	2.654	1.254	0.287

		3	-3.246	1.033	0.026
		4	-4.751	1.002	0.000
		5	-6.426	1.002	0.000
		6	-4.789	1.117	0.001
	3	1	5.900	1.329	0.000
		2	3.246	1.033	0.026
		4	-1.505	1.094	0.742
		5	-3.180	1.094	0.050
		6	-1.543	1.200	0.792
	4	1	7.405	1.305	0.000
		2	4.751	1.002	0.000
		3	1.505	1.094	0.742
		5	-1.675	1.065	0.618
		6	-0.038	1.174	1.000
	5	1	9.080	1.305	0.000
		2	6.426	1.002	0.000
		3	3.180	1.094	0.050
		4	1.675	1.065	0.618
		6	1.637	1.174	0.730
	6	1	7.443	1.395	0.000
		2	4.789	1.117	0.001
		3	1.543	1.200	0.792
		4	0.038	1.174	1.000
		5	-1.637	1.174	0.730
Max force	1	2	-152.723	67.562	0.220
		3	-490.467	71.611	0.000
		4	-406.000	70.321	0.000
		5	-393.750	70.321	0.000
		6	-400.657	75.176	0.000
	2	1	152.723	67.562	0.220
		3	-337.744	55.672	0.000
		4	-253.277	54.003	0.000
		5	-241.027	54.003	0.000
		6	-247.934	60.189	0.001
	3	1	490.467	71.611	0.000
		2	337.744	55.672	0.000
		4	84.467	58.990	0.708
		5	96.717	58.990	0.575
		6	89.810	64.701	0.734
	4	1	406.000	70.321	0.000
		2	253.277	54.003	0.000
		3	-84.467	58.990	0.708
		5	12.250	57.416	1.000
		6	5.343	63.270	1.000
	5	1	393.750	70.321	0.000
		2	241.027	54.003	0.000
		3	-96.717	58.990	0.575
		4	-12.250	57.416	1.000
		6	-6.907	63.270	1.000
	6	1	400.657	75.176	0.000
		2	247.934	60.189	0.001
		3	-89.810	64.701	0.734
		4	-5.343	63.270	1.000
		5	6.907	63.270	1.000
Sustained endurance time	1	2	-6.262	9.961	0.989
		3	-19.967	10.558	0.413
		4	-18.750	10.367	0.465
		5	-28.300	10.367	0.078
		6	-23.193	11.083	0.299
	2	1	6.262	9.961	0.989
		3	-13.705	8.208	0.555
		4	-12.488	7.962	0.621
		5	-22.038	7.962	0.071
		6	-16.931	8.874	0.403
	3	1	19.967	10.558	0.413
		2	13.705	8.208	0.555
		4	1.217	8.697	1.000
		5	-8.333	8.697	0.930
		6	-3.226	9.539	0.999
	4	1	18.750	10.367	0.465
		2	12.488	7.962	0.621

		3	-1.217	8.697	1.000
		5	-9.550	8.465	0.869
		6	-4.443	9.328	0.997
	5	1	28.300	10.367	0.078
		2	22.038	7.962	0.071
		3	8.333	8.697	0.930
		4	9.550	8.465	0.869
		6	5.107	9.328	0.994
	6	1	23.193	11.083	0.299
		2	16.931	8.874	0.403
		3	3.226	9.539	0.999
		4	4.443	9.328	0.997
		5	-5.107	9.328	0.994
IMF sustained	1	2	-7.265	5.872	0.817
		3	-3.928	6.224	0.988
		4	2.000	6.112	0.999
		5	2.523	6.112	0.998
		6	-4.971	6.534	0.973
	2	1	7.265	5.872	0.817
		3	3.338	4.839	0.983
		4	9.265	4.694	0.364
		5	9.788	4.694	0.303
		6	2.294	5.231	0.998
	3	1	3.928	6.224	0.988
		2	-3.338	4.839	0.983
		4	5.928	5.127	0.856
		5	6.451	5.127	0.807
		6	-1.044	5.623	1.000
	4	1	-2.000	6.112	0.999
		2	-9.265	4.694	0.364
		3	-5.928	5.127	0.856
		5	0.523	4.990	1.000
		6	-6.971	5.499	0.802
	5	1	-2.523	6.112	0.998
		2	-9.788	4.694	0.303
		3	-6.451	5.127	0.807
		4	-0.523	4.990	1.000
		6	-7.494	5.499	0.749
	6	1	4.971	6.534	0.973
		2	-2.294	5.231	0.998
		3	1.044	5.623	1.000
		4	6.971	5.499	0.802
		5	7.494	5.499	0.749
FMF sustained	1	2	2.135	7.459	1.000
		3	18.861	7.906	0.171
		4	16.650	7.764	0.273
		5	11.465	7.764	0.680
		6	9.679	8.300	0.852
	2	1	-2.135	7.459	1.000
		3	16.726	6.147	0.080
		4	14.515	5.962	0.154
		5	9.330	5.962	0.623
		6	7.544	6.645	0.866
	3	1	-18.861	7.906	0.171
		2	-16.726	6.147	0.080
		4	-2.211	6.513	0.999
		5	-7.396	6.513	0.865
		6	-9.183	7.143	0.792
	4	1	-16.650	7.764	0.273
		2	-14.515	5.962	0.154
		3	2.211	6.513	0.999
		5	-5.185	6.339	0.964
		6	-6.971	6.985	0.918
	5	1	-11.465	7.764	0.680
		2	-9.330	5.962	0.623
		3	7.396	6.513	0.865
		4	5.185	6.339	0.964
		6	-1.786	6.985	1.000
	6	1	-9.679	8.300	0.852
		2	-7.544	6.645	0.866
		3	9.183	7.143	0.792

		4	6.971	6.985	0.918
		5	1.786	6.985	1.000
IMF-FMF sustained	1	2	-9.400	5.698	0.568
		3	-22.789	6.039	0.004
		4	-14.650	5.930	0.143
		5	-8.817	5.930	0.673
		6	-14.614	6.340	0.202
	2	1	9.400	5.698	0.568
		3	-13.389	4.695	0.057
		4	-5.250	4.554	0.858
		5	0.583	4.554	1.000
		6	-5.214	5.076	0.908
	3	1	22.789	6.039	0.004
		2	13.389	4.695	0.057
		4	8.139	4.975	0.577
		5	13.972	4.975	0.064
		6	8.175	5.456	0.666
	4	1	14.650	5.930	0.143
		2	5.250	4.554	0.858
		3	-8.139	4.975	0.577
		5	5.833	4.842	0.834
		6	0.036	5.336	1.000
	5	1	8.817	5.930	0.673
		2	-0.583	4.554	1.000
		3	-13.972	4.975	0.064
		4	-5.833	4.842	0.834
		6	-5.797	5.336	0.886
	6	1	14.614	6.340	0.202
		2	5.214	5.076	0.908
		3	-8.175	5.456	0.666
		4	-0.036	5.336	1.000
		5	5.797	5.336	0.886
Hz/sec sustained	1	2	-0.141	0.104	0.748
		3	-0.182	0.110	0.566
		4	-0.062	0.108	0.993
		5	0.043	0.108	0.999
		6	-0.007	0.115	1.000
	2	1	0.141	0.104	0.748
		3	-0.040	0.085	0.997
		4	0.080	0.083	0.929
		5	0.184	0.083	0.236
		6	0.135	0.092	0.690
	3	1	0.182	0.110	0.566
		2	0.040	0.085	0.997
		4	0.120	0.091	0.770
		5	0.225	0.091	0.140
		6	0.175	0.099	0.494
	4	1	0.062	0.108	0.993
		2	-0.080	0.083	0.929
		3	-0.120	0.091	0.770
		5	0.105	0.088	0.843
		6	0.055	0.097	0.993
	5	1	-0.043	0.108	0.999
		2	-0.184	0.083	0.236
		3	-0.225	0.091	0.140
		4	-0.105	0.088	0.843
		6	-0.049	0.097	0.996
	6	1	0.007	0.115	1.000
		2	-0.135	0.092	0.690
		3	-0.175	0.099	0.494
		4	-0.055	0.097	0.993
		5	0.049	0.097	0.996
Intermittent endurance time	1	2	-35.269	36.497	0.927
		3	-33.167	38.685	0.956
		4	-61.700	37.988	0.585
		5	-117.750	37.988	0.029
		6	-104.143	40.610	0.116
	2	1	35.269	36.497	0.927
		3	2.103	30.075	1.000
		4	-26.431	29.173	0.944
		5	-82.481	29.173	0.061

		6	-68.874	32.514	0.286
	3	1	33.167	38.685	0.956
		2	-2.103	30.075	1.000
		4	-28.533	31.867	0.947
		5	-84.583	31.867	0.094
		6	-70.976	34.952	0.332
	4	1	61.700	37.988	0.585
		2	26.431	29.173	0.944
		3	28.533	31.867	0.947
		5	-56.050	31.017	0.466
		6	-42.443	34.179	0.815
	5	1	117.750	37.988	0.029
		2	82.481	29.173	0.061
		3	84.583	31.867	0.094
		4	56.050	31.017	0.466
		6	13.607	34.179	0.999
	6	1	104.143	40.610	0.116
		2	68.874	32.514	0.286
		3	70.976	34.952	0.332
		4	42.443	34.179	0.815
		5	-13.607	34.179	0.999
IMF intermittent	1	2	-5.727	6.130	0.937
		3	-5.689	6.498	0.952
		4	1.300	6.380	1.000
		5	0.000	6.380	1.000
		6	-8.800	6.821	0.790
	2	1	5.727	6.130	0.937
		3	0.038	5.051	1.000
		4	7.027	4.900	0.706
		5	5.727	4.900	0.851
		6	-3.073	5.461	0.993
	3	1	5.689	6.498	0.952
		2	-0.038	5.051	1.000
		4	6.989	5.352	0.781
		5	5.689	5.352	0.895
		6	-3.111	5.871	0.995
	4	1	-1.300	6.380	1.000
		2	-7.027	4.900	0.706
		3	-6.989	5.352	0.781
		5	-1.300	5.210	1.000
		6	-10.100	5.741	0.496
	5	1	0.000	6.380	1.000
		2	-5.727	4.900	0.851
		3	-5.689	5.352	0.895
		4	1.300	5.210	1.000
		6	-8.800	5.741	0.644
	6	1	8.800	6.821	0.790
		2	3.073	5.461	0.993
		3	3.111	5.871	0.995
		4	10.100	5.741	0.496
		5	8.800	5.741	0.644
FMF intermittent	1	2	-3.527	6.904	0.996
		3	-5.339	7.317	0.978
		4	8.775	7.185	0.826
		5	1.845	7.185	1.000
		6	-7.521	7.682	0.924
	2	1	3.527	6.904	0.996
		3	-1.812	5.689	1.000
		4	12.302	5.518	0.234
		5	5.372	5.518	0.925
		6	-3.995	6.150	0.987
	3	1	5.339	7.317	0.978
		2	1.812	5.689	1.000
		4	14.114	6.028	0.187
		5	7.184	6.028	0.840
		6	-2.183	6.611	0.999
	4	1	-8.775	7.185	0.826
		2	-12.302	5.518	0.234
		3	-14.114	6.028	0.187
		5	-6.930	5.867	0.845
		6	-16.296	6.465	0.128

	5	1	-1.845	7.185	1.000
		2	-5.372	5.518	0.925
		3	-7.184	6.028	0.840
		4	6.930	5.867	0.845
		6	-9.366	6.465	0.697
	6	1	7.521	7.682	0.924
		2	3.995	6.150	0.987
		3	2.183	6.611	0.999
		4	16.296	6.465	0.128
		5	9.366	6.465	0.697
IMF-FMF intermittent	1	2	-2.200	4.011	0.994
		3	-0.350	4.251	1.000
		4	-7.475	4.174	0.476
		5	-1.845	4.174	0.998
		6	-1.243	4.463	1.000
	2	1	2.200	4.011	0.994
		3	1.850	3.305	0.993
		4	-5.275	3.206	0.571
		5	0.355	3.206	1.000
		6	0.957	3.573	1.000
	3	1	0.350	4.251	1.000
		2	-1.850	3.305	0.993
		4	-7.125	3.502	0.330
		5	-1.495	3.502	0.998
		6	-0.893	3.841	1.000
	4	1	7.475	4.174	0.476
		2	5.275	3.206	0.571
		3	7.125	3.502	0.330
		5	5.630	3.408	0.567
		6	6.232	3.756	0.562
	5	1	1.845	4.174	0.998
		2	-0.355	3.206	1.000
		3	1.495	3.502	0.998
		4	-5.630	3.408	0.567
		6	0.602	3.756	1.000
	6	1	1.243	4.463	1.000
		2	-0.957	3.573	1.000
		3	0.893	3.841	1.000
		4	-6.232	3.756	0.562
		5	-0.602	3.756	1.000
Hz/sec intermittent	1	2	0.016	0.031	0.995
		3	0.028	0.033	0.960
		4	-0.014	0.032	0.998
		5	0.039	0.032	0.831
		6	0.044	0.035	0.802
	2	1	-0.016	0.031	0.995
		3	0.011	0.026	0.998
		4	-0.030	0.025	0.835
		5	0.023	0.025	0.941
		6	0.028	0.028	0.919
	3	1	-0.028	0.033	0.960
		2	-0.011	0.026	0.998
		4	-0.041	0.027	0.658
		5	0.012	0.027	0.998
		6	0.016	0.030	0.994
	4	1	0.014	0.032	0.998
		2	0.030	0.025	0.835
		3	0.041	0.027	0.658
		5	0.053	0.026	0.353
		6	0.057	0.029	0.366
	5	1	-0.039	0.032	0.831
		2	-0.023	0.025	0.941
		3	-0.012	0.027	0.998
		4	-0.053	0.026	0.353
		6	0.005	0.029	1.000
	6	1	-0.044	0.035	0.802
		2	-0.028	0.028	0.919
		3	-0.016	0.030	0.994
		4	-0.057	0.029	0.366
		5	-0.005	0.029	1.000
Systolic BP before contraction	1	2	-11.015	4.845	0.215

		3	-17.789	5.135	0.010
		4	-16.350	5.043	0.019
		5	-24.500	5.043	0.000
		6	-32.971	5.391	0.000
	2	1	11.015	4.845	0.215
		3	-6.774	3.992	0.537
		4	-5.335	3.873	0.740
		5	-13.485	3.873	0.009
		6	-21.956	4.316	0.000
	3	1	17.789	5.135	0.010
		2	6.774	3.992	0.537
		4	1.439	4.230	0.999
		5	-6.711	4.230	0.609
		6	-15.183	4.640	0.018
	4	1	16.350	5.043	0.019
		2	5.335	3.873	0.740
		3	-1.439	4.230	0.999
		5	-8.150	4.118	0.361
		6	-16.621	4.537	0.005
	5	1	24.500	5.043	0.000
		2	13.485	3.873	0.009
		3	6.711	4.230	0.609
		4	8.150	4.118	0.361
		6	-8.471	4.537	0.428
	6	1	32.971	5.391	0.000
		2	21.956	4.316	0.000
		3	15.183	4.640	0.018
		4	16.621	4.537	0.005
		5	8.471	4.537	0.428
Systolic BP after sustained	1	2	-7.631	6.139	0.815
		3	-19.956	6.507	0.032
		4	-16.700	6.390	0.103
		5	-29.700	6.390	0.000
		6	-39.114	6.831	0.000
	2	1	7.631	6.139	0.815
		3	-12.325	5.059	0.154
		4	-9.069	4.907	0.440
		5	-22.069	4.907	0.000
		6	-31.484	5.469	0.000
	3	1	19.956	6.507	0.032
		2	12.325	5.059	0.154
		4	3.256	5.360	0.990
		5	-9.744	5.360	0.459
		6	-19.159	5.879	0.018
	4	1	16.700	6.390	0.103
		2	9.069	4.907	0.440
		3	-3.256	5.360	0.990
		5	-13.000	5.217	0.136
		6	-22.414	5.749	0.002
	5	1	29.700	6.390	0.000
		2	22.069	4.907	0.000
		3	9.744	5.360	0.459
		4	13.000	5.217	0.136
		6	-9.414	5.749	0.576
	6	1	39.114	6.831	0.000
		2	31.484	5.469	0.000
		3	19.159	5.879	0.018
		4	22.414	5.749	0.002
		5	9.414	5.749	0.576
Difference of systolic BP (sustained)	1	2	3.385	4.982	0.984
		3	-2.167	5.280	0.998
		4	-0.350	5.185	1.000
		5	-5.200	5.185	0.916
		6	-6.143	5.543	0.877
	2	1	-3.385	4.982	0.984
		3	-5.551	4.105	0.755
		4	-3.735	3.982	0.936
		5	-8.585	3.982	0.268
		6	-9.527	4.438	0.272
	3	1	2.167	5.280	0.998
		2	5.551	4.105	0.755

		4	1.817	4.350	0.998
		5	-3.033	4.350	0.982
		6	-3.976	4.771	0.961
	4	1	0.350	5.185	1.000
		2	3.735	3.982	0.936
		3	-1.817	4.350	0.998
		5	-4.850	4.234	0.861
		6	-5.793	4.665	0.815
	5	1	5.200	5.185	0.916
		2	8.585	3.982	0.268
		3	3.033	4.350	0.982
		4	4.850	4.234	0.861
		6	-0.943	4.665	1.000
	6	1	6.143	5.543	0.877
		2	9.527	4.438	0.272
		3	3.976	4.771	0.961
		4	5.793	4.665	0.815
		5	0.943	4.665	1.000
Diastolic BP before contraction	1	2	-7.885	3.486	0.220
		3	-9.111	3.695	0.144
		4	-15.000	3.629	0.001
		5	-20.600	3.629	0.000
		6	-21.286	3.879	0.000
	2	1	7.885	3.486	0.220
		3	-1.226	2.873	0.998
		4	-7.115	2.787	0.119
		5	-12.715	2.787	0.000
		6	-13.401	3.106	0.001
	3	1	9.111	3.695	0.144
		2	1.226	2.873	0.998
		4	-5.889	3.044	0.387
		5	-11.489	3.044	0.004
		6	-12.175	3.339	0.005
	4	1	15.000	3.629	0.001
		2	7.115	2.787	0.119
		3	5.889	3.044	0.387
		5	-5.600	2.963	0.414
		6	-6.286	3.265	0.393
	5	1	20.600	3.629	0.000
		2	12.715	2.787	0.000
		3	11.489	3.044	0.004
		4	5.600	2.963	0.414
		6	-0.686	3.265	1.000
	6	1	21.286	3.879	0.000
		2	13.401	3.106	0.001
		3	12.175	3.339	0.005
		4	6.286	3.265	0.393
		5	0.686	3.265	1.000
Diastolic BP after sustained	1	2	-5.562	5.399	0.907
		3	-2.822	5.722	0.996
		4	-10.100	5.619	0.472
		5	-13.350	5.619	0.175
		6	-19.314	6.007	0.021
	2	1	5.562	5.399	0.907
		3	2.739	4.449	0.990
		4	-4.538	4.315	0.899
		5	-7.788	4.315	0.467
		6	-13.753	4.809	0.056
	3	1	2.822	5.722	0.996
		2	-2.739	4.449	0.990
		4	-7.278	4.714	0.637
		5	-10.528	4.714	0.232
		6	-16.492	5.170	0.023
	4	1	10.100	5.619	0.472
		2	4.538	4.315	0.899
		3	7.278	4.714	0.637
		5	-3.250	4.588	0.981
		6	-9.214	5.056	0.456
	5	1	13.350	5.619	0.175
		2	7.788	4.315	0.467
		3	10.528	4.714	0.232

		4	3.250	4.588	0.981
		6	-5.964	5.056	0.846
	6	1	19.314	6.007	0.021
		2	13.753	4.809	0.056
		3	16.492	5.170	0.023
		4	9.214	5.056	0.456
		5	5.964	5.056	0.846
Difference of diastolic(sustained)	1	2	2.323	4.665	0.996
		3	6.289	4.945	0.800
		4	4.900	4.855	0.914
		5	7.250	4.855	0.669
		6	1.971	5.191	0.999
	2	1	-2.323	4.665	0.996
		3	3.966	3.844	0.906
		4	2.577	3.729	0.983
		5	4.927	3.729	0.773
		6	-0.352	4.156	1.000
	3	1	-6.289	4.945	0.800
		2	-3.966	3.844	0.906
		4	-1.389	4.073	0.999
		5	0.961	4.073	1.000
		6	-4.317	4.467	0.927
	4	1	-4.900	4.855	0.914
		2	-2.577	3.729	0.983
		3	1.389	4.073	0.999
		5	2.350	3.964	0.991
		6	-2.929	4.369	0.985
	5	1	-7.250	4.855	0.669
		2	-4.927	3.729	0.773
		3	-0.961	4.073	1.000
		4	-2.350	3.964	0.991
		6	-5.279	4.369	0.832
	6	1	-1.971	5.191	0.999
		2	0.352	4.156	1.000
		3	4.317	4.467	0.927
		4	2.929	4.369	0.985
		5	5.279	4.369	0.832
HR before contraction	1	2	8.631	4.901	0.495
		3	17.622	5.195	0.012
		4	10.050	5.102	0.367
		5	8.650	5.102	0.538
		6	8.329	5.454	0.648
	2	1	-8.631	4.901	0.495
		3	8.991	4.039	0.235
		4	1.419	3.918	0.999
		5	0.019	3.918	1.000
		6	-0.302	4.366	1.000
	3	1	-17.622	5.195	0.012
		2	-8.991	4.039	0.235
		4	-7.572	4.280	0.490
		5	-8.972	4.280	0.297
		6	-9.294	4.694	0.361
	4	1	-10.050	5.102	0.367
		2	-1.419	3.918	0.999
		3	7.572	4.280	0.490
		5	-1.400	4.165	0.999
		6	-1.721	4.590	0.999
	5	1	-8.650	5.102	0.538
		2	-0.019	3.918	1.000
		3	8.972	4.280	0.297
		4	1.400	4.165	0.999
		6	-0.321	4.590	1.000
	6	1	-8.329	5.454	0.648
		2	0.302	4.366	1.000
		3	9.294	4.694	0.361
		4	1.721	4.590	0.999
		5	0.321	4.590	1.000
HR after sustained	1	2	18.962	5.313	0.007
		3	24.778	5.632	0.000
		4	19.100	5.530	0.010
		5	19.250	5.530	0.009

		6	17.429	5.912	0.045
	2	1	-18.962	5.313	0.007
		3	5.816	4.378	0.769
		4	0.138	4.247	1.000
		5	0.288	4.247	1.000
		6	-1.533	4.734	1.000
	3	1	-24.778	5.632	0.000
		2	-5.816	4.378	0.769
		4	-5.678	4.639	0.824
		5	-5.528	4.639	0.840
		6	-7.349	5.088	0.700
	4	1	-19.100	5.530	0.010
		2	-0.138	4.247	1.000
		3	5.678	4.639	0.824
		5	0.150	4.516	1.000
		6	-1.671	4.976	0.999
	5	1	-19.250	5.530	0.009
		2	-0.288	4.247	1.000
		3	5.528	4.639	0.840
		4	-0.150	4.516	1.000
		6	-1.821	4.976	0.999
	6	1	-17.429	5.912	0.045
		2	1.533	4.734	1.000
		3	7.349	5.088	0.700
		4	1.671	4.976	0.999
		5	1.821	4.976	0.999
Difference of HR after sustained	1	2	10.331	3.533	0.047
		3	7.156	3.745	0.402
		4	9.050	3.677	0.146
		5	10.600	3.677	0.053
		6	9.100	3.931	0.198
	2	1	-10.331	3.533	0.047
		3	-3.175	2.911	0.884
		4	-1.281	2.824	0.998
		5	0.269	2.824	1.000
		6	-1.231	3.147	0.999
	3	1	-7.156	3.745	0.402
		2	3.175	2.911	0.884
		4	1.894	3.085	0.990
		5	3.444	3.085	0.873
		6	1.944	3.383	0.992
	4	1	-9.050	3.677	0.146
		2	1.281	2.824	0.998
		3	-1.894	3.085	0.990
		5	1.550	3.002	0.995
		6	0.050	3.308	1.000
	5	1	-10.600	3.677	0.053
		2	-0.269	2.824	1.000
		3	-3.444	3.085	0.873
		4	-1.550	3.002	0.995
		6	-1.500	3.308	0.998
	6	1	-9.100	3.931	0.198
		2	1.231	3.147	0.999
		3	-1.944	3.383	0.992
		4	-0.050	3.308	1.000
		5	1.500	3.308	0.998
Sys BP after intermittent	1	2	-3.169	7.261	0.998
		3	-11.067	7.696	0.704
		4	-9.350	7.557	0.818
		5	-19.650	7.557	0.107
		6	-32.329	8.079	0.002
	2	1	3.169	7.261	0.998
		3	-7.897	5.983	0.773
		4	-6.181	5.804	0.894
		5	-16.481	5.804	0.059
		6	-29.159	6.469	0.000
	3	1	11.067	7.696	0.704
		2	7.897	5.983	0.773
		4	1.717	6.340	1.000
		5	-8.583	6.340	0.754
		6	-21.262	6.954	0.033

	4	1	9.350	7.557	0.818
		2	6.181	5.804	0.894
		3	-1.717	6.340	1.000
		5	-10.300	6.171	0.555
		6	-22.979	6.800	0.013
	5	1	19.650	7.557	0.107
		2	16.481	5.804	0.059
		3	8.583	6.340	0.754
		4	10.300	6.171	0.555
		6	-12.679	6.800	0.430
	6	1	32.329	8.079	0.002
		2	29.159	6.469	0.000
		3	21.262	6.954	0.033
		4	22.979	6.800	0.013
		5	12.679	6.800	0.430
Difference of systolic BP (Intermittent)	1	2	7.846	6.409	0.824
		3	6.722	6.793	0.920
		4	7.000	6.670	0.900
		5	4.850	6.670	0.978
		6	0.643	7.131	1.000
	2	1	-7.846	6.409	0.824
		3	-1.124	5.281	1.000
		4	-0.846	5.122	1.000
		5	-2.996	5.122	0.992
		6	-7.203	5.709	0.805
	3	1	-6.722	6.793	0.920
		2	1.124	5.281	1.000
		4	0.278	5.595	1.000
		5	-1.872	5.595	0.999
		6	-6.079	6.137	0.920
	4	1	-7.000	6.670	0.900
		2	0.846	5.122	1.000
		3	-0.278	5.595	1.000
		5	-2.150	5.446	0.999
		6	-6.357	6.001	0.896
	5	1	-4.850	6.670	0.978
		2	2.996	5.122	0.992
		3	1.872	5.595	0.999
		4	2.150	5.446	0.999
		6	-4.207	6.001	0.981
	6	1	-0.643	7.131	1.000
		2	7.203	5.709	0.805
		3	6.079	6.137	0.920
		4	6.357	6.001	0.896
		5	4.207	6.001	0.981
Diastolic BP after intermittent	1	2	9.554	5.426	0.496
		3	8.678	5.752	0.659
		4	1.900	5.648	0.999
		5	-6.200	5.648	0.881
		6	-13.814	6.038	0.209
	2	1	-9.554	5.426	0.496
		3	-0.876	4.471	1.000
		4	-7.654	4.337	0.493
		5	-15.754	4.337	0.006
		6	-23.368	4.834	0.000
	3	1	-8.678	5.752	0.659
		2	0.876	4.471	1.000
		4	-6.778	4.738	0.708
		5	-14.878	4.738	0.026
		6	-22.492	5.197	0.000
	4	1	-1.900	5.648	0.999
		2	7.654	4.337	0.493
		3	6.778	4.738	0.708
		5	-8.100	4.612	0.498
		6	-15.714	5.082	0.030
	5	1	6.200	5.648	0.881
		2	15.754	4.337	0.006
		3	14.878	4.738	0.026
		4	8.100	4.612	0.498
		6	-7.614	5.082	0.666
	6	1	13.814	6.038	0.209

		2	23.368	4.834	0.000
		3	22.492	5.197	0.000
		4	15.714	5.082	0.030
		5	7.614	5.082	0.666
Difference of diastolic BP (intermittent)	1	2	17.438	4.833	0.006
		3	17.789	5.123	0.010
		4	16.900	5.031	0.014
		5	14.400	5.031	0.056
		6	7.471	5.378	0.733
	2	1	-17.438	4.833	0.006
		3	0.350	3.983	1.000
		4	-0.538	3.863	1.000
		5	-3.038	3.863	0.969
		6	-9.967	4.306	0.198
	3	1	-17.789	5.123	0.010
		2	-0.350	3.983	1.000
		4	-0.889	4.220	1.000
		5	-3.389	4.220	0.966
		6	-10.317	4.629	0.234
	4	1	-16.900	5.031	0.014
		2	0.538	3.863	1.000
		3	0.889	4.220	1.000
		5	-2.500	4.108	0.990
		6	-9.429	4.526	0.304
	5	1	-14.400	5.031	0.056
		2	3.038	3.863	0.969
		3	3.389	4.220	0.966
		4	2.500	4.108	0.990
		6	-6.929	4.526	0.645
	6	1	-7.471	5.378	0.733
		2	9.967	4.306	0.198
		3	10.317	4.629	0.234
		4	9.429	4.526	0.304
		5	6.929	4.526	0.645
HR after intermittent	1	2	7.292	5.311	0.743
		3	20.544	5.629	0.005
		4	11.300	5.527	0.325
		5	15.400	5.527	0.068
		6	11.457	5.909	0.385
	2	1	-7.292	5.311	0.743
		3	13.252	4.376	0.036
		4	4.008	4.245	0.934
		5	8.108	4.245	0.402
		6	4.165	4.731	0.950
	3	1	-20.544	5.629	0.005
		2	-13.252	4.376	0.036
		4	-9.244	4.637	0.353
		5	-5.144	4.637	0.876
		6	-9.087	5.086	0.479
	4	1	-11.300	5.527	0.325
		2	-4.008	4.245	0.934
		3	9.244	4.637	0.353
		5	4.100	4.513	0.944
		6	0.157	4.973	1.000
	5	1	-15.400	5.527	0.068
		2	-8.108	4.245	0.402
		3	5.144	4.637	0.876
		4	-4.100	4.513	0.944
		6	-3.943	4.973	0.968
	6	1	-11.457	5.909	0.385
		2	-4.165	4.731	0.950
		3	9.087	5.086	0.479
		4	-0.157	4.973	1.000
		5	3.943	4.973	0.968
Difference of HR (intermittent)	1	2	-1.338	3.347	0.999
		3	2.922	3.548	0.963
		4	1.250	3.484	0.999
		5	6.750	3.484	0.386
		6	3.129	3.724	0.959
	2	1	1.338	3.347	0.999
		3	4.261	2.758	0.636

		4	2.588	2.675	0.927
		5	8.088	2.675	0.036
		6	4.467	2.982	0.666
	3	1	-2.922	3.548	0.963
		2	-4.261	2.758	0.636
		4	-1.672	2.922	0.993
		5	3.828	2.922	0.779
		6	0.206	3.205	1.000
	4	1	-1.250	3.484	0.999
		2	-2.588	2.675	0.927
		3	1.672	2.922	0.993
		5	5.500	2.844	0.388
		6	1.879	3.134	0.991
	5	1	-6.750	3.484	0.386
		2	-8.088	2.675	0.036
		3	-3.828	2.922	0.779
		4	-5.500	2.844	0.388
		6	-3.621	3.134	0.857
	6	1	-3.129	3.724	0.959
		2	-4.467	2.982	0.666
		3	-0.206	3.205	1.000
		4	-1.879	3.134	0.991
		5	3.621	3.134	0.857
Initial half relaxation time	1	2	0.007	0.015	0.997
		3	-0.002	0.016	1.000
		4	0.003	0.016	1.000
		5	-0.018	0.016	0.855
		6	-0.004	0.017	1.000
	2	1	-0.007	0.015	0.997
		3	-0.009	0.013	0.974
		4	-0.004	0.012	0.999
		5	-0.026	0.012	0.286
		6	-0.012	0.014	0.951
	3	1	0.002	0.016	1.000
		2	0.009	0.013	0.974
		4	0.005	0.013	0.999
		5	-0.016	0.013	0.824
		6	-0.002	0.015	1.000
	4	1	-0.003	0.016	1.000
		2	0.004	0.012	0.999
		3	-0.005	0.013	0.999
		5	-0.021	0.013	0.564
		6	-0.008	0.014	0.995
	5	1	0.018	0.016	0.855
		2	0.026	0.012	0.286
		3	0.016	0.013	0.824
		4	0.021	0.013	0.564
		6	0.014	0.014	0.926
	6	1	0.004	0.017	1.000
		2	0.012	0.014	0.951
		3	0.002	0.015	1.000
		4	0.008	0.014	0.995
		5	-0.014	0.014	0.926
Final half relaxation time	1	2	0.017	0.019	0.944
		3	-0.013	0.020	0.988
		4	0.003	0.020	1.000
		5	-0.010	0.020	0.996
		6	-0.004	0.021	1.000
	2	1	-0.017	0.019	0.944
		3	-0.030	0.016	0.397
		4	-0.014	0.015	0.942
		5	-0.027	0.015	0.488
		6	-0.022	0.017	0.798
	3	1	0.013	0.020	0.988
		2	0.030	0.016	0.397
		4	0.016	0.017	0.925
		5	0.003	0.017	1.000
		6	0.009	0.018	0.997
	4	1	-0.003	0.020	1.000
		2	0.014	0.015	0.942
		3	-0.016	0.017	0.925

		5	-0.013	0.016	0.965
		6	-0.008	0.018	0.998
	5	1	0.010	0.020	0.996
		2	0.027	0.015	0.488
		3	-0.003	0.017	1.000
		4	0.013	0.016	0.965
		6	0.005	0.018	1.000
	6	1	0.004	0.021	1.000
		2	0.022	0.017	0.798
		3	-0.009	0.018	0.997
		4	0.008	0.018	0.998
		5	-0.005	0.018	1.000
Half relaxation time change	1	2	0.010	0.010	0.909
		3	-0.011	0.010	0.902
		4	0.000	0.010	1.000
		5	0.009	0.010	0.961
		6	0.000	0.011	1.000
	2	1	-0.010	0.010	0.909
		3	-0.021	0.008	0.110
		4	-0.010	0.008	0.818
		5	-0.002	0.008	1.000
		6	-0.010	0.009	0.864
	3	1	0.011	0.010	0.902
		2	0.021	0.008	0.110
		4	0.011	0.009	0.780
		5	0.019	0.009	0.220
		6	0.011	0.009	0.852
	4	1	0.000	0.010	1.000
		2	0.010	0.008	0.818
		3	-0.011	0.009	0.780
		5	0.008	0.008	0.924
		6	0.000	0.009	1.000
	5	1	-0.009	0.010	0.961
		2	0.002	0.008	1.000
		3	-0.019	0.009	0.220
		4	-0.008	0.008	0.924
		6	-0.008	0.009	0.942
	6	1	0.000	0.011	1.000
		2	0.010	0.009	0.864
		3	-0.011	0.009	0.852
		4	0.000	0.009	1.000
		5	0.008	0.009	0.942

IMF = Initial median frequency
FMF = Final median frequency

APPENDIX 4

Descriptive by age in females					
Characteristic		N	Mean	Std. Deviation	Std. Error
	Age group				
Weight	1	5	32.600	10.784	4.823
	2	13	48.385	10.540	2.923
	3	9	62.778	5.263	1.754
	4	10	62.600	9.559	3.023
	5	10	66.600	11.721	3.706
	6	6	60.000	14.642	5.978
	Total	53	56.774	14.331	1.968
Height	1	5	1.308	0.114	0.051
	2	13	1.549	0.095	0.026
	3	9	1.694	0.081	0.027
	4	10	1.658	0.053	0.017
	5	10	1.622	0.057	0.018
	6	6	1.640	0.062	0.025
	Total	53	1.596	0.130	0.018
BMI	1	5	18.640	3.955	1.769
	2	13	19.931	2.595	0.720
	3	9	21.878	1.278	0.426
	4	10	22.700	2.612	0.826
	5	10	25.320	4.269	1.350
	6	6	22.183	4.525	1.847
	Total	53	21.934	3.699	0.508
Max force*	1	5	200.000	110.374	49.361
	2	13	340.385	96.958	26.891
	3	9	536.556	110.454	36.818
	4	10	449.800	94.212	29.793
	5	10	428.300	89.594	28.332
	6	6	400.667	80.343	32.800
	Total	53	404.509	130.775	17.963
Sustained endurance time	1	5	44.600	8.706	3.894
	2	13	54.615	29.233	8.108
	3	9	67.444	27.514	9.171
	4	10	67.600	19.552	6.183
	5	10	84.700	53.431	16.896
	6	6	82.000	29.853	12.187
	Total	53	67.075	33.740	4.635
IMF sustained	1	5	86.400	11.524	5.154
	2	13	84.038	12.331	3.420
	3	9	86.056	9.593	3.198
	4	10	83.400	15.529	4.911
	5	10	82.350	17.944	5.675
	6	6	86.833	16.437	6.710
	Total	53	84.481	13.619	1.871
FMF sustained	1	5	56.800	16.053	7.179
	2	13	49.423	15.399	4.271
	3	9	38.056	12.375	4.125
	4	10	43.750	23.132	7.315
	5	10	55.630	24.050	7.605
	6	6	49.500	27.984	11.424
	Total	53	48.298	20.150	2.768
IMF-FMF sustained	1	5	29.600	15.339	6.860
	2	13	34.615	11.932	3.309
	3	9	48.000	16.008	5.336
	4	10	39.650	10.698	3.383
	5	10	26.470	13.401	4.238
	6	6	37.333	20.235	8.261
	Total	53	36.136	15.172	2.084
Hz/sec sustained	1	5	0.687	0.353	0.158
	2	13	0.701	0.252	0.070
	3	9	0.754	0.275	0.092
	4	10	0.621	0.204	0.065
	5	10	0.428	0.207	0.065
	6	6	0.489	0.306	0.125
	Total	53	0.618	0.272	0.037
Intermittent endurance time	1	5	125.000	31.623	14.142
	2	13	157.692	73.757	20.456
	3	9	176.111	59.832	19.944
	4	10	215.800	106.321	33.622

	5	10	293.000	134.767	42.617
	6	6	301.667	149.321	60.960
	Total	53	210.528	114.039	15.665
IMF intermittent	1	5	87.800	11.841	5.295
	2	13	84.192	11.738	3.255
	3	9	90.667	10.735	3.578
	4	10	89.050	16.432	5.196
	5	10	88.600	13.721	4.339
	6	6	94.833	16.678	6.809
	Total	53	88.585	13.287	1.825
FMF intermittent	1	5	67.800	18.714	8.369
	2	13	66.500	14.891	4.130
	3	9	76.333	10.654	3.551
	4	10	67.850	18.870	5.967
	5	10	74.800	16.047	5.075
	6	6	81.417	13.463	5.496
	Total	53	71.802	15.707	2.158
IMF-FMF intermittent	1	5	20.000	9.670	4.324
	2	13	17.692	9.499	2.635
	3	9	14.333	7.365	2.455
	4	10	21.200	14.808	4.683
	5	10	13.800	9.659	3.054
	6	6	13.417	8.902	3.634
	Total	53	16.783	10.348	1.421
Hz/sec intermittent	1	5	0.178	0.111	0.050
	2	13	0.125	0.074	0.020
	3	9	0.089	0.044	0.015
	4	10	0.128	0.107	0.034
	5	10	0.052	0.036	0.011
	6	6	0.060	0.054	0.022
	Total	53	0.103	0.081	0.011
Systolic BP before contraction	1	5	92.200	13.755	6.151
	2	13	108.231	11.826	3.280
	3	9	108.667	6.964	2.321
	4	10	109.400	12.213	3.862
	5	10	119.500	11.702	3.701
	6	6	126.500	23.535	9.608
	Total	53	111.208	15.361	2.110
Systolic BP after sustained	1	5	104.800	18.485	8.267
	2	13	112.000	14.961	4.149
	3	9	121.111	12.898	4.299
	4	10	121.800	11.302	3.574
	5	10	134.500	11.984	3.790
	6	6	140.000	20.919	8.540
	Total	53	122.132	17.708	2.432
Difference of systolic BP (sustained)	1	5	12.600	11.327	5.066
	2	13	3.769	12.558	3.483
	3	9	12.444	9.302	3.101
	4	10	12.400	10.080	3.187
	5	10	15.000	13.679	4.326
	6	6	13.500	12.373	5.051
	Total	53	10.925	11.921	1.637
Diastolic BP before contraction	1	5	58.800	15.106	6.756
	2	13	70.000	11.321	3.140
	3	9	66.333	9.000	3.000
	4	10	74.800	3.360	1.062
	5	10	79.100	7.187	2.273
	6	6	86.333	11.183	4.566
	Total	53	72.792	11.836	1.626
Diastolic BP after sustained	1	5	64.800	24.692	11.043
	2	13	69.000	18.102	5.020
	3	9	68.222	10.317	3.439
	4	10	76.100	7.795	2.465
	5	10	76.600	13.015	4.116
	6	6	90.000	13.957	5.698
	Total	53	73.623	15.785	2.168
Difference of diastolic (sustained)	1	5	6.000	10.654	4.764
	2	13	-1.000	17.311	4.801
	3	9	1.889	8.507	2.836
	4	10	1.300	6.865	2.171
	5	10	-2.500	12.886	4.075

	6	6	3.667	4.502	1.838
	Total	53	0.830	11.600	1.593
HR before contraction	1	5	73.400	13.539	6.055
	2	13	71.077	12.842	3.562
	3	9	65.556	13.154	4.385
	4	10	72.500	13.542	4.282
	5	10	74.900	8.863	2.803
	6	6	79.833	16.092	6.570
	Total	53	72.340	12.854	1.766
HR after sustained	1	5	88.400	8.019	3.586
	2	13	66.385	14.598	4.049
	3	9	68.889	15.161	5.054
	4	10	70.900	17.330	5.480
	5	10	72.300	10.520	3.327
	6	6	76.667	17.716	7.233
	Total	53	72.019	15.132	2.079
Difference of HR after sustained	1	5	15.000	15.116	6.760
	2	13	-4.692	13.212	3.664
	3	9	3.333	9.206	3.069
	4	10	-1.600	6.450	2.040
	5	10	-2.600	7.877	2.491
	6	6	-3.167	6.401	2.613
	Total	53	-0.321	11.166	1.534
Sys BP after intermittent	1	5	121.400	25.511	11.409
	2	13	120.846	24.474	6.788
	3	9	121.556	13.182	4.394
	4	10	124.100	15.567	4.923
	5	10	128.900	14.138	4.471
	6	6	141.500	29.938	12.222
	Total	53	125.491	20.484	2.814
Difference of systolic BP (Intermittent)	1	5	29.200	29.668	13.268
	2	13	12.615	22.838	6.334
	3	9	12.889	7.590	2.530
	4	10	14.700	12.239	3.870
	5	10	9.400	11.928	3.772
	6	6	15.000	11.593	4.733
	Total	53	14.283	16.956	2.329
Diastolic BP after intermittent	1	5	82.800	36.643	16.387
	2	13	69.308	18.697	5.186
	3	9	65.667	9.760	3.253
	4	10	71.400	7.891	2.495
	5	10	78.600	11.520	3.643
	6	6	86.333	16.955	6.922
	Total	53	74.038	17.547	2.410
Difference of diastolic BP (intermittent)	1	5	24.000	29.992	13.413
	2	13	-0.692	14.620	4.055
	3	9	-0.667	10.062	3.354
	4	10	-3.400	6.132	1.939
	5	10	-0.500	11.394	3.603
	6	6	0.000	7.294	2.978
	Total	53	1.245	14.982	2.058
HR after intermittent	1	5	76.400	14.188	6.345
	2	13	77.769	12.930	3.586
	3	9	66.444	14.117	4.706
	4	10	73.800	15.683	4.959
	5	10	72.300	10.478	3.313
	6	6	80.167	16.916	6.906
	Total	53	74.208	13.882	1.907
Difference of HR (intermittent)	1	5	3.000	21.119	9.445
	2	13	6.692	11.535	3.199
	3	9	0.889	8.894	2.965
	4	10	1.300	8.314	2.629
	5	10	-2.600	7.763	2.455
	6	6	0.333	2.733	1.116
	Total	53	1.868	10.516	1.444
Initial half relaxation time	1	5	0.095	0.041	0.018
	2	13	0.083	0.021	0.006
	3	9	0.093	0.026	0.009
	4	10	0.096	0.059	0.019
	5	10	0.124	0.062	0.020
	6	6	0.078	0.033	0.014

	Total	53	0.095	0.044	0.006
Final half relaxation time	1	5	0.144	0.057	0.025
	2	13	0.124	0.028	0.008
	3	9	0.144	0.026	0.009
	4	10	0.143	0.074	0.024
	5	10	0.163	0.070	0.022
	6	6	0.123	0.056	0.023
	Total	53	0.140	0.053	0.007
Half relaxation time change	1	5	0.049	0.025	0.011
	2	13	0.040	0.017	0.005
	3	9	0.051	0.023	0.008
	4	10	0.047	0.024	0.008
	5	10	0.038	0.018	0.006
	6	6	0.045	0.032	0.013
	Total	53	0.044	0.022	0.003

* The unit is milli volt
IMF = Initial median frequency
FMF = Final median frequency

Multiple Comparisons				
Tukey HSD				
			Std. Error	Sig.
Dependent Variable	Age group	Age group		
Weight	1	2	5.509	0.064
		3	5.839	0.000
		4	5.734	0.000
		5	5.734	0.000
		6	6.339	0.001
	2	1	5.509	0.064
		3	4.539	0.030
		4	4.403	0.026
		5	4.403	0.002
		6	5.167	0.236
	3	1	5.839	0.000
		2	4.539	0.030
		4	4.810	1.000
		5	4.810	0.967
		6	5.517	0.996
	4	1	5.734	0.000
		2	4.403	0.026
		3	4.810	1.000
		5	4.682	0.955
		6	5.406	0.997
	5	1	5.734	0.000
		2	4.403	0.002
		3	4.810	0.967
		4	4.682	0.955
		6	5.406	0.824
	6	1	6.339	0.001
		2	5.167	0.236
		3	5.517	0.996
		4	5.406	0.997
		5	5.406	0.824
Height	1	2	0.041	0.000
		3	0.044	0.000
		4	0.043	0.000
		5	0.043	0.000
		6	0.047	0.000
	2	1	0.041	0.000
		3	0.034	0.001
		4	0.033	0.021
		5	0.033	0.253
		6	0.039	0.196
	3	1	0.044	0.000
		2	0.034	0.001
		4	0.036	0.911
		5	0.036	0.350
		6	0.041	0.773
	4	1	0.043	0.000
		2	0.033	0.021
		3	0.036	0.911
		5	0.035	0.906
		6	0.040	0.998
	5	1	0.043	0.000
		2	0.033	0.253
		3	0.036	0.350
		4	0.035	0.906
		6	0.040	0.998
	6	1	0.047	0.000
		2	0.039	0.196
		3	0.041	0.773
		4	0.040	0.998
		5	0.040	0.998
BMI	1	2	1.689	0.972
		3	1.790	0.470
		4	1.758	0.211
		5	1.758	0.005
		6	1.944	0.461
	2	1	1.689	0.972
		3	1.392	0.727

		4	1.350	0.330
		5	1.350	0.003
		6	1.584	0.714
	3	1	1.790	0.470
		2	1.392	0.727
		4	1.475	0.993
		5	1.475	0.201
		6	1.692	1.000
	4	1	1.758	0.211
		2	1.350	0.330
		3	1.475	0.993
		5	1.435	0.460
		6	1.658	1.000
	5	1	1.758	0.005
		2	1.350	0.003
		3	1.475	0.201
		4	1.435	0.460
		6	1.658	0.419
	6	1	1.944	0.461
		2	1.584	0.714
		3	1.692	1.000
		4	1.658	1.000
		5	1.658	0.419
Max force	1	2	51.121	0.085
		3	54.185	0.000
		4	53.208	0.000
		5	53.208	0.001
		6	58.824	0.016
	2	1	51.121	0.085
		3	42.125	0.000
		4	40.861	0.099
		5	40.861	0.280
		6	47.946	0.806
	3	1	54.185	0.000
		2	42.125	0.000
		4	44.635	0.389
		5	44.635	0.169
		6	51.200	0.104
	4	1	53.208	0.000
		2	40.861	0.099
		3	44.635	0.389
		5	43.444	0.996
		6	50.165	0.922
	5	1	53.208	0.001
		2	40.861	0.280
		3	44.635	0.169
		4	43.444	0.996
		6	50.165	0.994
	6	1	58.824	0.016
		2	47.946	0.806
		3	51.200	0.104
		4	50.165	0.922
		5	50.165	0.994
Sustained duration	1	2	17.199	0.992
		3	18.230	0.808
		4	17.901	0.792
		5	17.901	0.239
		6	19.791	0.421
	2	1	17.199	0.992
		3	14.172	0.943
		4	13.747	0.933
		5	13.747	0.262
		6	16.131	0.540
	3	1	18.230	0.808
		2	14.172	0.943
		4	15.017	1.000
		5	15.017	0.858
		6	17.226	0.957
	4	1	17.901	0.792
		2	13.747	0.933
		3	15.017	1.000

		5	14.616	0.849
		6	16.878	0.956
	5	1	17.901	0.239
		2	13.747	0.262
		3	15.017	0.858
		4	14.616	0.849
		6	16.878	1.000
	6	1	19.791	0.421
		2	16.131	0.540
		3	17.226	0.957
		4	16.878	0.956
		5	16.878	1.000
IMF sustained	1	2	7.486	1.000
		3	7.935	1.000
		4	7.792	0.999
		5	7.792	0.995
		6	8.614	1.000
	2	1	7.486	1.000
		3	6.169	0.999
		4	5.984	1.000
		5	5.984	1.000
		6	7.021	0.999
	3	1	7.935	1.000
		2	6.169	0.999
		4	6.536	0.998
		5	6.536	0.993
		6	7.498	1.000
	4	1	7.792	0.999
		2	5.984	1.000
		3	6.536	0.998
		5	6.362	1.000
		6	7.346	0.997
	5	1	7.792	0.995
		2	5.984	1.000
		3	6.536	0.993
		4	6.362	1.000
		6	7.346	0.990
	6	1	8.614	1.000
		2	7.021	0.999
		3	7.498	1.000
		4	7.346	0.997
		5	7.346	0.990
FMF sustained	1	2	10.591	0.981
		3	11.226	0.558
		4	11.024	0.842
		5	11.024	1.000
		6	12.187	0.991
	2	1	10.591	0.981
		3	8.727	0.782
		4	8.466	0.984
		5	8.466	0.977
		6	9.933	1.000
	3	1	11.226	0.558
		2	8.727	0.782
		4	9.247	0.989
		5	9.247	0.415
		6	10.608	0.887
	4	1	11.024	0.842
		2	8.466	0.984
		3	9.247	0.989
		5	9.001	0.773
		6	10.393	0.993
	5	1	11.024	1.000
		2	8.466	0.977
		3	9.247	0.415
		4	9.001	0.773
		6	10.393	0.991
	6	1	12.187	0.991
		2	9.933	1.000
		3	10.608	0.887
		4	10.393	0.993

		5	10.393	0.991
IMF-FMF sustained	1	2	7.439	0.984
		3	7.885	0.201
		4	7.743	0.785
		5	7.743	0.999
		6	8.560	0.944
	2	1	7.439	0.984
		3	6.130	0.265
		4	5.946	0.957
		5	5.946	0.744
		6	6.977	0.999
	3	1	7.885	0.201
		2	6.130	0.265
		4	6.496	0.791
		5	6.496	0.021
		6	7.451	0.708
	4	1	7.743	0.785
		2	5.946	0.957
		3	6.496	0.791
		5	6.322	0.313
		6	7.300	1.000
	5	1	7.743	0.999
		2	5.946	0.744
		3	6.496	0.021
		4	6.322	0.313
		6	7.300	0.673
	6	1	8.560	0.944
		2	6.977	0.999
		3	7.451	0.708
		4	7.300	1.000
		5	7.300	0.673
Hz/sec sustained	1	2	0.135	1.000
		3	0.143	0.997
		4	0.141	0.997
		5	0.141	0.448
		6	0.155	0.795
	2	1	0.135	1.000
		3	0.111	0.997
		4	0.108	0.976
		5	0.108	0.136
		6	0.127	0.551
	3	1	0.143	0.997
		2	0.111	0.997
		4	0.118	0.866
		5	0.118	0.081
		6	0.135	0.376
	4	1	0.141	0.997
		2	0.108	0.976
		3	0.118	0.866
		5	0.115	0.549
		6	0.132	0.915
	5	1	0.141	0.448
		2	0.108	0.136
		3	0.118	0.081
		4	0.115	0.549
		6	0.132	0.997
	6	1	0.155	0.795
		2	0.127	0.551
		3	0.135	0.376
		4	0.132	0.915
		5	0.132	0.997
Intermittent duration	1	2	52.880	0.989
		3	56.050	0.942
		4	55.040	0.571
		5	55.040	0.041
		6	60.849	0.059
	2	1	52.880	0.989
		3	43.575	0.998
		4	42.268	0.742
		5	42.268	0.028
		6	49.596	0.059

	3	1	56.050	0.942
		2	43.575	0.998
		4	46.171	0.954
		5	46.171	0.136
		6	52.962	0.188
	4	1	55.040	0.571
		2	42.268	0.742
		3	46.171	0.954
		5	44.940	0.527
		6	51.892	0.568
	5	1	55.040	0.041
		2	42.268	0.028
		3	46.171	0.136
		4	44.940	0.527
		6	51.892	1.000
	6	1	60.849	0.059
		2	49.596	0.059
		3	52.962	0.188
		4	51.892	0.568
		5	51.892	1.000
IMF intermittent	1	2	7.140	0.996
		3	7.568	0.999
		4	7.431	1.000
		5	7.431	1.000
		6	8.215	0.955
	2	1	7.140	0.996
		3	5.883	0.879
		4	5.707	0.956
		5	5.707	0.971
		6	6.696	0.610
	3	1	7.568	0.999
		2	5.883	0.879
		4	6.234	1.000
		5	6.234	0.999
		6	7.151	0.992
	4	1	7.431	1.000
		2	5.707	0.956
		3	6.234	1.000
		5	6.068	1.000
		6	7.006	0.961
	5	1	7.431	1.000
		2	5.707	0.971
		3	6.234	0.999
		4	6.068	1.000
		6	7.006	0.947
	6	1	8.215	0.955
		2	6.696	0.610
		3	7.151	0.992
		4	7.006	0.961
		5	7.006	0.947
FMF intermittent	1	2	8.195	1.000
		3	8.686	0.921
		4	8.530	1.000
		5	8.530	0.962
		6	9.430	0.700
	2	1	8.195	1.000
		3	6.753	0.693
		4	6.550	1.000
		5	6.550	0.801
		6	7.686	0.391
	3	1	8.686	0.921
		2	6.753	0.693
		4	7.155	0.841
		5	7.155	1.000
		6	8.208	0.989
	4	1	8.530	1.000
		2	6.550	1.000
		3	7.155	0.841
		5	6.964	0.916
		6	8.042	0.547
	5	1	8.530	0.962

		2	6.550	0.801
		3	7.155	1.000
		4	6.964	0.916
		6	8.042	0.962
	6	1	9.430	0.700
		2	7.686	0.391
		3	8.208	0.989
		4	8.042	0.547
		5	8.042	0.962
IMF-EMF intermittent	1	2	5.482	0.998
		3	5.810	0.924
		4	5.706	1.000
		5	5.706	0.884
		6	6.308	0.901
	2	1	5.482	0.998
		3	4.517	0.975
		4	4.382	0.966
		5	4.382	0.947
		6	5.141	0.960
	3	1	5.810	0.924
		2	4.517	0.975
		4	4.786	0.706
		5	4.786	1.000
		6	5.490	1.000
	4	1	5.706	1.000
		2	4.382	0.966
		3	4.786	0.706
		5	4.659	0.610
		6	5.379	0.699
	5	1	5.706	0.884
		2	4.382	0.947
		3	4.786	1.000
		4	4.659	0.610
		6	5.379	1.000
	6	1	6.308	0.901
		2	5.141	0.960
		3	5.490	1.000
		4	5.379	0.699
		5	5.379	1.000
Hz/sec intermittent	1	2	0.039	0.744
		3	0.041	0.282
		4	0.041	0.812
		5	0.041	0.035
		6	0.045	0.111
	2	1	0.039	0.744
		3	0.032	0.880
		4	0.031	1.000
		5	0.031	0.198
		6	0.037	0.502
	3	1	0.041	0.282
		2	0.032	0.880
		4	0.034	0.871
		5	0.034	0.874
		6	0.039	0.975
	4	1	0.041	0.812
		2	0.031	1.000
		3	0.034	0.871
		5	0.033	0.218
		6	0.038	0.503
	5	1	0.041	0.035
		2	0.031	0.198
		3	0.034	0.874
		4	0.033	0.218
		6	0.038	1.000
	6	1	0.045	0.111
		2	0.037	0.502
		3	0.039	0.975
		4	0.038	0.503
		5	0.038	1.000
Systolic BP before contraction	1	2	6.937	0.210
		3	7.353	0.240

		4	7.220	0.183
		5	7.220	0.006
		6	7.982	0.001
	2	1	6.937	0.210
		3	5.716	1.000
		4	5.545	1.000
		5	5.545	0.340
		6	6.506	0.074
	3	1	7.353	0.240
		2	5.716	1.000
		4	6.057	1.000
		5	6.057	0.483
		6	6.948	0.126
	4	1	7.220	0.183
		2	5.545	1.000
		3	6.057	1.000
		5	5.895	0.530
		6	6.807	0.141
	5	1	7.220	0.006
		2	5.545	0.340
		3	6.057	0.483
		4	5.895	0.530
		6	6.807	0.906
	6	1	7.982	0.001
		2	6.506	0.074
		3	6.948	0.126
		4	6.807	0.141
		5	6.807	0.906
Systolic BP after sustained	1	2	7.681	0.935
		3	8.142	0.356
		4	7.995	0.292
		5	7.995	0.007
		6	8.839	0.003
	2	1	7.681	0.935
		3	6.329	0.703
		4	6.140	0.605
		5	6.140	0.008
		6	7.204	0.004
	3	1	8.142	0.356
		2	6.329	0.703
		4	6.707	1.000
		5	6.707	0.360
		6	7.693	0.159
	4	1	7.995	0.292
		2	6.140	0.605
		3	6.707	1.000
		5	6.528	0.388
		6	7.538	0.172
	5	1	7.995	0.007
		2	6.140	0.008
		3	6.707	0.360
		4	6.528	0.388
		6	7.538	0.977
	6	1	8.839	0.003
		2	7.204	0.004
		3	7.693	0.159
		4	7.538	0.172
		5	7.538	0.977
Difference of systolic BP (sustained)	1	2	6.170	0.708
		3	6.540	1.000
		4	6.422	1.000
		5	6.422	0.999
		6	7.100	1.000
	2	1	6.170	0.708
		3	5.084	0.535
		4	4.932	0.507
		5	4.932	0.224
		6	5.787	0.550
	3	1	6.540	1.000
		2	5.084	0.535
		4	5.387	1.000

		5	5.387	0.997
		6	6.180	1.000
	4	1	6.422	1.000
		2	4.932	0.507
		3	5.387	1.000
		5	5.244	0.996
		6	6.055	1.000
	5	1	6.422	0.999
		2	4.932	0.224
		3	5.387	0.997
		4	5.244	0.996
		6	6.055	1.000
	6	1	7.100	1.000
		2	5.787	0.550
		3	6.180	1.000
		4	6.055	1.000
		5	6.055	1.000
Diastolic BP before contraction	1	2	5.028	0.245
		3	5.329	0.719
		4	5.233	0.040
		5	5.233	0.004
		6	5.786	0.000
	2	1	5.028	0.245
		3	4.143	0.948
		4	4.019	0.837
		5	4.019	0.229
		6	4.716	0.014
	3	1	5.329	0.719
		2	4.143	0.948
		4	4.390	0.398
		5	4.390	0.058
		6	5.036	0.003
	4	1	5.233	0.040
		2	4.019	0.837
		3	4.390	0.398
		5	4.273	0.914
		6	4.934	0.200
	5	1	5.233	0.004
		2	4.019	0.229
		3	4.390	0.058
		4	4.273	0.914
		6	4.934	0.687
	6	1	5.786	0.000
		2	4.716	0.014
		3	5.036	0.003
		4	4.934	0.200
		5	4.934	0.687
Diastolic BP after sustained	1	2	7.778	0.994
		3	8.244	0.998
		4	8.096	0.729
		5	8.096	0.692
		6	8.950	0.072
	2	1	7.778	0.994
		3	6.409	1.000
		4	6.217	0.861
		5	6.217	0.824
		6	7.295	0.062
	3	1	8.244	0.998
		2	6.409	1.000
		4	6.791	0.853
		5	6.791	0.818
		6	7.790	0.076
	4	1	8.096	0.729
		2	6.217	0.861
		3	6.791	0.853
		5	6.610	1.000
		6	7.633	0.463
	5	1	8.096	0.692
		2	6.217	0.824
		3	6.791	0.818
		4	6.610	1.000

		6	7.633	0.503
	6	1	8.950	0.072
		2	7.295	0.062
		3	7.790	0.076
		4	7.633	0.463
		5	7.633	0.503
Difference of diastolic(sustained)	1	2	6.259	0.871
		3	6.634	0.989
		4	6.515	0.978
		5	6.515	0.781
		6	7.202	0.999
	2	1	6.259	0.871
		3	5.158	0.993
		4	5.003	0.997
		5	5.003	1.000
		6	5.870	0.967
	3	1	6.634	0.989
		2	5.158	0.993
		4	5.465	1.000
		5	5.465	0.966
		6	6.269	1.000
	4	1	6.515	0.978
		2	5.003	0.997
		3	5.465	1.000
		5	5.319	0.979
		6	6.142	0.999
	5	1	6.515	0.781
		2	5.003	1.000
		3	5.465	0.966
		4	5.319	0.979
		6	6.142	0.914
	6	1	7.202	0.999
		2	5.870	0.967
		3	6.269	1.000
		4	6.142	0.999
		5	6.142	0.914
HR before contraction	1	2	6.757	0.999
		3	7.162	0.881
		4	7.033	1.000
		5	7.033	1.000
		6	7.775	0.961
	2	1	6.757	0.999
		3	5.568	0.918
		4	5.401	1.000
		5	5.401	0.980
		6	6.337	0.737
	3	1	7.162	0.881
		2	5.568	0.918
		4	5.900	0.845
		5	5.900	0.613
		6	6.767	0.300
	4	1	7.033	1.000
		2	5.401	1.000
		3	5.900	0.845
		5	5.742	0.998
		6	6.631	0.876
	5	1	7.033	1.000
		2	5.401	0.980
		3	5.900	0.613
		4	5.742	0.998
		6	6.631	0.975
	6	1	7.775	0.961
		2	6.337	0.737
		3	6.767	0.300
		4	6.631	0.876
		5	6.631	0.975
HR after sustained	1	2	7.646	0.062
		3	8.104	0.175
		4	7.958	0.258
		5	7.958	0.345
		6	8.798	0.765

	2	1	7.646	0.062
		3	6.300	0.999
		4	6.111	0.976
		5	6.111	0.926
		6	7.171	0.707
	3	1	8.104	0.175
		2	6.300	0.999
		4	6.676	1.000
		5	6.676	0.996
		6	7.658	0.910
	4	1	7.958	0.258
		2	6.111	0.976
		3	6.676	1.000
		5	6.498	1.000
		6	7.503	0.971
	5	1	7.958	0.345
		2	6.111	0.926
		3	6.676	0.996
		4	6.498	1.000
		6	7.503	0.992
	6	1	8.798	0.765
		2	7.171	0.707
		3	7.658	0.910
		4	7.503	0.971
		5	7.503	0.992
Difference of HR after sustained	1	2	5.332	0.007
		3	5.651	0.323
		4	5.549	0.047
		5	5.549	0.030
		6	6.135	0.051
	2	1	5.332	0.007
		3	4.393	0.459
		4	4.262	0.978
		5	4.262	0.996
		6	5.000	1.000
	3	1	5.651	0.323
		2	4.393	0.459
		4	4.655	0.895
		5	4.655	0.797
		6	5.340	0.826
	4	1	5.549	0.047
		2	4.262	0.978
		3	4.655	0.895
		5	4.531	1.000
		6	5.232	1.000
	5	1	5.549	0.030
		2	4.262	0.996
		3	4.655	0.797
		4	4.531	1.000
		6	5.232	1.000
	6	1	6.135	0.051
		2	5.000	1.000
		3	5.340	0.826
		4	5.232	1.000
		5	5.232	1.000
Sys BP after intermittent	1	2	10.758	1.000
		3	11.403	1.000
		4	11.197	1.000
		5	11.197	0.984
		6	12.379	0.587
	2	1	10.758	1.000
		3	8.865	1.000
		4	8.599	0.999
		5	8.599	0.935
		6	10.090	0.332
	3	1	11.403	1.000
		2	8.865	1.000
		4	9.393	1.000
		5	9.393	0.969
		6	10.775	0.444
	4	1	11.197	1.000

		2	8.599	0.999
		3	9.393	1.000
		5	9.142	0.995
		6	10.557	0.572
	5	1	11.197	0.984
		2	8.599	0.935
		3	9.393	0.969
		4	9.142	0.995
		6	10.557	0.838
	6	1	12.379	0.587
		2	10.090	0.332
		3	10.775	0.444
		4	10.557	0.572
		5	10.557	0.838
Difference of systolic BP (Intermittent)	1	2	8.932	0.441
		3	9.468	0.524
		4	9.297	0.628
		5	9.297	0.290
		6	10.278	0.738
	2	1	8.932	0.441
		3	7.360	1.000
		4	7.140	1.000
		5	7.140	0.998
		6	8.377	1.000
	3	1	9.468	0.524
		2	7.360	1.000
		4	7.799	1.000
		5	7.799	0.998
		6	8.946	1.000
	4	1	9.297	0.628
		2	7.140	1.000
		3	7.799	1.000
		5	7.591	0.981
		6	8.765	1.000
	5	1	9.297	0.290
		2	7.140	0.998
		3	7.799	0.998
		4	7.591	0.981
		6	8.765	0.987
	6	1	10.278	0.738
		2	8.377	1.000
		3	8.946	1.000
		4	8.765	1.000
		5	8.765	0.987
Diastolic BP after intermittent	1	2	8.925	0.659
		3	9.460	0.469
		4	9.290	0.821
		5	9.290	0.997
		6	10.270	0.999
	2	1	8.925	0.659
		3	7.354	0.996
		4	7.134	1.000
		5	7.134	0.782
		6	8.371	0.339
	3	1	9.460	0.469
		2	7.354	0.996
		4	7.793	0.976
		5	7.793	0.564
		6	8.939	0.210
	4	1	9.290	0.821
		2	7.134	1.000
		3	7.793	0.976
		5	7.585	0.931
		6	8.758	0.535
	5	1	9.290	0.997
		2	7.134	0.782
		3	7.793	0.564
		4	7.585	0.931
		6	8.758	0.949
	6	1	10.270	0.999
		2	8.371	0.339

		3	8.939	0.210
		4	8.758	0.535
		5	8.758	0.949
Difference of diastolic BP (intermittent)	1	2	7.178	0.015
		3	7.609	0.025
		4	7.472	0.008
		5	7.472	0.023
		6	8.260	0.059
	2	1	7.178	0.015
		3	5.915	1.000
		4	5.738	0.997
		5	5.738	1.000
		6	6.733	1.000
	3	1	7.609	0.025
		2	5.915	1.000
		4	6.268	0.998
		5	6.268	1.000
		6	7.189	1.000
	4	1	7.472	0.008
		2	5.738	0.997
		3	6.268	0.998
		5	6.100	0.997
		6	7.044	0.997
	5	1	7.472	0.023
		2	5.738	1.000
		3	6.268	1.000
		4	6.100	0.997
		6	7.044	1.000
	6	1	8.260	0.059
		2	6.733	1.000
		3	7.189	1.000
		4	7.044	0.997
		5	7.044	1.000
HR after intermittent	1	2	7.297	1.000
		3	7.735	0.790
		4	7.595	0.999
		5	7.595	0.994
		6	8.397	0.998
	2	1	7.297	1.000
		3	6.013	0.425
		4	5.833	0.983
		5	5.833	0.935
		6	6.844	0.999
	3	1	7.735	0.790
		2	6.013	0.425
		4	6.372	0.856
		5	6.372	0.940
		6	7.309	0.428
	4	1	7.595	0.999
		2	5.833	0.983
		3	6.372	0.856
		5	6.202	1.000
		6	7.161	0.947
	5	1	7.595	0.994
		2	5.833	0.935
		3	6.372	0.940
		4	6.202	1.000
		6	7.161	0.879
	6	1	8.397	0.998
		2	6.844	0.999
		3	7.309	0.428
		4	7.161	0.947
		5	7.161	0.879
Difference of HR (intermittent)	1	2	5.543	0.985
		3	5.876	0.999
		4	5.770	1.000
		5	5.770	0.925
		6	6.379	0.998
	2	1	5.543	0.985
		3	4.568	0.799
		4	4.431	0.826

		5	4.431	0.306
		6	5.199	0.823
	3	1	5.876	0.999
		2	4.568	0.799
		4	4.840	1.000
		5	4.840	0.978
		6	5.552	1.000
	4	1	5.770	1.000
		2	4.431	0.826
		3	4.840	1.000
		5	4.711	0.961
		6	5.440	1.000
	5	1	5.770	0.925
		2	4.431	0.306
		3	4.840	0.978
		4	4.711	0.961
		6	5.440	0.994
	6	1	6.379	0.998
		2	5.199	0.823
		3	5.552	1.000
		4	5.440	1.000
		5	5.440	0.994
Initial half relaxation time	1	2	0.023	0.996
		3	0.024	1.000
		4	0.024	1.000
		5	0.024	0.814
		6	0.026	0.987
	2	1	0.023	0.996
		3	0.019	0.996
		4	0.018	0.984
		5	0.018	0.240
		6	0.021	1.000
	3	1	0.024	1.000
		2	0.019	0.996
		4	0.020	1.000
		5	0.020	0.621
		6	0.023	0.985
	4	1	0.024	1.000
		2	0.018	0.984
		3	0.020	1.000
		5	0.019	0.685
		6	0.022	0.965
	5	1	0.024	0.814
		2	0.018	0.240
		3	0.020	0.621
		4	0.019	0.685
		6	0.022	0.316
	6	1	0.026	0.987
		2	0.021	1.000
		3	0.023	0.985
		4	0.022	0.965
		5	0.022	0.316
Final half relaxation time	1	2	0.028	0.981
		3	0.030	1.000
		4	0.030	1.000
		5	0.030	0.987
		6	0.033	0.988
	2	1	0.028	0.981
		3	0.023	0.949
		4	0.023	0.959
		5	0.023	0.529
		6	0.027	1.000
	3	1	0.030	1.000
		2	0.023	0.949
		4	0.025	1.000
		5	0.025	0.976
		6	0.029	0.974
	4	1	0.030	1.000
		2	0.023	0.959
		3	0.025	1.000
		5	0.024	0.961

		6	0.028	0.980
	5	1	0.030	0.987
		2	0.023	0.529
		3	0.025	0.976
		4	0.024	0.961
		6	0.028	0.711
	6	1	0.033	0.988
		2	0.027	1.000
		3	0.029	0.974
		4	0.028	0.980
		5	0.028	0.711
Half relaxation time change	1	2	0.012	0.978
		3	0.012	1.000
		4	0.012	1.000
		5	0.012	0.955
		6	0.014	1.000
	2	1	0.012	0.978
		3	0.010	0.859
		4	0.009	0.980
		5	0.009	1.000
		6	0.011	0.998
	3	1	0.012	1.000
		2	0.010	0.859
		4	0.010	0.998
		5	0.010	0.799
		6	0.012	0.995
	4	1	0.012	1.000
		2	0.009	0.980
		3	0.010	0.998
		5	0.010	0.954
		6	0.012	1.000
	5	1	0.012	0.955
		2	0.009	1.000
		3	0.010	0.799
		4	0.010	0.954
		6	0.012	0.991
	6	1	0.014	1.000
		2	0.011	0.998
		3	0.012	0.995
		4	0.012	1.000
		5	0.012	0.991

APPENDIX 5

Descriptive by age in males					
Characteristic					
		N	Mean	Std. Deviation	Std. Error
	Age group				
Weight	1	5	25.600	4.615	2.064
	2	13	47.769	10.117	2.806
	3	9	75.333	9.682	3.227
	4	10	80.400	15.960	5.047
	5	10	85.900	15.132	4.785
	6	8	86.125	12.867	4.549
	Total	55	68.709	23.457	3.163
Height	1	5	1.296	0.117	0.052
	2	13	1.572	0.094	0.026
	3	9	1.781	0.048	0.016
	4	10	1.759	0.061	0.019
	5	10	1.793	0.079	0.025
	6	8	1.818	0.073	0.026
	Total	55	1.691	0.173	0.023
BMI	1	5	15.160	1.113	0.498
	2	13	19.177	2.913	0.808
	3	9	23.722	2.789	0.930
	4	10	25.910	4.464	1.411
	5	10	26.640	3.772	1.193
	6	8	25.963	2.344	0.829
	Total	55	23.124	4.913	0.662
Max force	1	5	205.400	84.364	37.729
	2	13	370.462	163.028	45.216
	3	9	849.778	144.098	48.033
	4	10	767.600	128.868	40.752
	5	10	764.600	120.404	38.075
	6	8	755.375	158.699	56.109
	Total	55	633.745	260.948	35.186
Sustained endurance time	1	5	43.800	17.908	8.009
	2	13	46.308	26.186	7.263
	3	9	60.889	10.043	3.348
	4	10	58.300	16.499	5.218
	5	10	60.300	12.455	3.939
	6	8	56.438	18.608	6.579
	Total	55	54.664	18.713	2.523
IMF sustained	1	5	79.800	11.541	5.161
	2	13	96.692	18.341	5.087
	3	9	88.000	18.486	6.162
	4	10	78.800	13.919	4.402
	5	10	78.804	15.796	4.995
	6	8	89.000	21.534	7.613
	Total	55	86.110	17.930	2.418
FMF sustained	1	5	61.200	3.768	1.685
	2	13	64.308	26.004	7.212
	3	9	42.222	11.832	3.944
	4	10	40.950	19.990	6.321
	5	10	39.440	19.928	6.302
	6	8	49.188	19.168	6.777
	Total	55	49.444	21.426	2.889
IMF-FMF sustained	1	5	18.600	15.291	6.838
	2	13	32.385	18.343	5.087
	3	9	45.778	11.922	3.974
	4	10	37.850	12.257	3.876
	5	10	39.364	17.132	5.418
	6	8	39.750	21.354	7.550
	Total	55	36.657	17.254	2.327
Hz/sec sustained	1	5	0.481	0.324	0.145
	2	13	0.750	0.403	0.112
	3	9	0.777	0.247	0.082
	4	10	0.671	0.212	0.067
	5	10	0.655	0.280	0.089
	6	8	0.667	0.227	0.080
	Total	55	0.686	0.295	0.040
Intermittent endurance time	1	5	131.000	33.053	14.782
	2	13	168.846	102.655	28.471
	3	9	146.222	34.164	11.388
	4	10	163.600	47.629	15.062

	5	10	198.500	153.805	48.637
	6	8	180.000	52.440	18.540
	Total	55	167.764	87.613	11.814
IMF intermittent	1	5	83.600	7.603	3.400
	2	13	98.662	22.821	6.329
	3	9	92.111	13.348	4.449
	4	10	79.750	19.421	6.142
	5	10	82.800	17.515	5.539
	6	8	94.250	20.541	7.262
	Total	55	89.256	19.206	2.590
FMF intermittent	1	5	70.300	6.996	3.129
	2	13	78.654	26.304	7.295
	3	9	72.444	10.608	3.536
	4	10	52.700	20.938	6.621
	5	10	59.610	18.627	5.890
	6	8	72.938	22.842	8.076
	Total	55	67.865	21.533	2.903
IMF-FMF intermittent	1	5	13.300	4.550	2.035
	2	13	20.008	11.857	3.288
	3	9	19.667	7.653	2.551
	4	10	27.050	16.249	5.138
	5	10	23.190	7.040	2.226
	6	8	21.250	9.189	3.249
	Total	55	21.382	10.873	1.466
Hz/sec intermittent	1	5	0.107	0.047	0.021
	2	13	0.128	0.056	0.016
	3	9	0.140	0.060	0.020
	4	10	0.185	0.137	0.043
	5	10	0.155	0.088	0.028
	6	8	0.127	0.068	0.024
	Total	55	0.143	0.084	0.011
Systolic BP before contraction	1	5	103.000	10.977	4.909
	2	13	109.000	9.857	2.734
	3	9	122.111	8.192	2.731
	4	10	118.500	13.125	4.151
	5	10	124.700	12.962	4.099
	6	8	133.625	17.096	6.044
	Total	55	118.764	14.905	2.010
Systolic BP after sustained	1	5	107.400	17.155	7.672
	2	13	115.462	21.133	5.861
	3	9	131.000	21.517	7.172
	4	10	123.800	11.243	3.555
	5	10	137.100	14.075	4.451
	6	8	149.125	23.031	8.143
	Total	55	127.618	21.810	2.941
Difference of systolic BP (sustained)	1	5	4.400	8.678	3.881
	2	13	6.462	21.524	5.970
	3	9	8.889	21.780	7.260
	4	10	5.300	6.734	2.129
	5	10	12.400	9.180	2.903
	6	8	15.500	7.801	2.758
	Total	55	8.855	14.924	2.012
Diastolic BP before contraction	1	5	59.200	8.526	3.813
	2	13	63.769	10.561	2.929
	3	9	69.889	5.840	1.947
	4	10	73.200	7.480	2.365
	5	10	80.100	7.141	2.258
	6	8	75.750	12.464	4.407
	Total	55	70.782	10.881	1.467
Diastolic BP after sustained	1	5	64.000	20.712	9.263
	2	13	70.923	22.104	6.130
	3	9	66.222	11.200	3.733
	4	10	72.900	7.578	2.397
	5	10	78.900	7.781	2.461
	6	8	79.000	12.083	4.272
	Total	55	72.509	15.008	2.024
Difference of diastolic (sustained)	1	5	4.800	15.353	6.866
	2	13	7.154	22.233	6.166
	3	9	-3.667	11.136	3.712
	4	10	-0.300	7.514	2.376
	5	10	-1.200	5.692	1.800

	6	8	3.250	4.132	1.461
	Total	55	1.727	13.349	1.800
HR before contraction	1	5	89.400	12.075	5.400
	2	13	74.462	13.087	3.630
	3	9	62.000	10.920	3.640
	4	10	70.200	11.952	3.779
	5	10	70.600	9.070	2.868
	6	8	68.000	20.563	7.270
	Total	55	71.364	14.420	1.944
HR after sustained	1	5	92.600	18.889	8.447
	2	13	76.692	11.161	3.095
	3	9	62.556	14.501	4.834
	4	10	71.900	12.827	4.056
	5	10	70.200	11.811	3.735
	6	8	70.375	18.738	6.625
	Total	55	72.855	15.529	2.094
Difference of HR after sustained	1	5	3.200	7.259	3.247
	2	13	2.231	12.962	3.595
	3	9	0.556	6.167	2.056
	4	10	1.700	6.750	2.135
	5	10	-0.400	6.899	2.182
	6	8	2.375	4.173	1.475
	Total	55	1.491	8.124	1.095
Sys BP after intermittent	1	5	107.800	18.308	8.188
	2	13	114.692	19.851	5.506
	3	9	129.778	19.917	6.639
	4	10	123.800	11.351	3.589
	5	10	139.600	17.322	5.478
	6	8	151.000	24.489	8.658
	Total	55	128.000	22.536	3.039
Difference of systolic BP (Intermittent)	1	5	4.800	12.377	5.535
	2	13	5.692	19.482	5.403
	3	9	7.667	19.066	6.355
	4	10	5.300	15.492	4.899
	5	10	14.900	16.536	5.229
	6	8	17.375	14.550	5.144
	Total	55	9.236	16.925	2.282
Diastolic BP after intermittent	1	5	66.000	18.439	8.246
	2	13	60.385	10.556	2.928
	3	9	65.778	10.710	3.570
	4	10	73.600	7.306	2.310
	5	10	82.600	8.343	2.638
	6	8	89.625	17.262	6.103
	Total	55	72.473	15.343	2.069
Difference of diastolic BP (intermittent)	1	5	6.800	11.122	4.974
	2	13	-3.385	11.318	3.139
	3	9	-4.111	8.609	2.870
	4	10	0.400	7.427	2.349
	5	10	2.500	6.468	2.045
	6	8	13.875	21.873	7.733
	Total	55	1.691	12.784	1.724
HR after intermittent	1	5	94.800	10.756	4.810
	2	13	78.846	12.144	3.368
	3	9	63.667	16.530	5.510
	4	10	74.800	15.817	5.002
	5	10	68.100	10.546	3.335
	6	8	69.625	19.654	6.949
	Total	55	73.782	16.278	2.195
Difference of HR (intermittent)	1	5	5.400	3.209	1.435
	2	13	4.385	9.170	2.543
	3	9	1.667	8.231	2.744
	4	10	4.600	9.789	3.096
	5	10	-2.500	6.060	1.916
	6	8	1.625	4.470	1.580
	Total	55	2.418	7.840	1.057
Initial half relaxation time	1	5	0.088	0.024	0.011
	2	13	0.085	0.035	0.010
	3	9	0.094	0.036	0.012
	4	10	0.081	0.036	0.011
	5	10	0.095	0.035	0.011
	6	8	0.110	0.056	0.020

	Total	55	0.091	0.038	0.005
Final half relaxation time	1	5	0.138	0.046	0.021
	2	13	0.123	0.036	0.010
	3	9	0.163	0.045	0.015
	4	10	0.132	0.052	0.017
	5	10	0.138	0.047	0.015
	6	8	0.162	0.075	0.027
	Total	55	0.141	0.050	0.007
Half relaxation time change	1	5	0.049	0.032	0.014
	2	13	0.038	0.034	0.009
	3	9	0.069	0.033	0.011
	4	10	0.051	0.022	0.007
	5	10	0.043	0.026	0.008
	6	8	0.052	0.036	0.013
	Total	55	0.049	0.031	0.004

* The unit is milli volt

IMF = Initial median frequency

FMF = Final median frequency

Multiple Comparisons in males				
Tukey HSD				
			Std. Error	Sig.
Dependent Variable	Age group	Age group		
Weight	1	2	6.543	0.017
		3	6.935	0.000
		4	6.810	0.000
		5	6.810	0.000
		6	7.089	0.000
	2	1	6.543	0.017
		3	5.392	0.000
		4	5.230	0.000
		5	5.230	0.000
		6	5.587	0.000
	3	1	6.935	0.000
		2	5.392	0.000
		4	5.713	0.948
		5	5.713	0.445
		6	6.042	0.484
	4	1	6.810	0.000
		2	5.230	0.000
		3	5.713	0.948
		5	5.561	0.919
		6	5.898	0.925
	5	1	6.810	0.000
		2	5.230	0.000
		3	5.713	0.445
		4	5.561	0.919
		6	5.898	1.000
	6	1	7.089	0.000
		2	5.587	0.000
		3	6.042	0.484
		4	5.898	0.925
		5	5.898	1.000
Height	1	2	0.042	0.000
		3	0.044	0.000
		4	0.043	0.000
		5	0.043	0.000
		6	0.045	0.000
	2	1	0.042	0.000
		3	0.034	0.000
		4	0.033	0.000
		5	0.033	0.000
		6	0.035	0.000
	3	1	0.044	0.000
		2	0.034	0.000
		4	0.036	0.990
		5	0.036	0.999
		6	0.038	0.932
	4	1	0.043	0.000
		2	0.033	0.000
		3	0.036	0.990
		5	0.035	0.927
		6	0.037	0.627
	5	1	0.043	0.000
		2	0.033	0.000
		3	0.036	0.999
		4	0.035	0.927
		6	0.037	0.986
	6	1	0.045	0.000
		2	0.035	0.000
		3	0.038	0.932
		4	0.037	0.627
		5	0.037	0.986
BMI	1	2	1.706	0.193
		3	1.808	0.000
		4	1.775	0.000
		5	1.775	0.000
		6	1.848	0.000
	2	1	1.706	0.193
		3	1.406	0.025

		4	1.363	0.000
		5	1.363	0.000
		6	1.457	0.000
	3	1	1.808	0.000
		2	1.406	0.025
		4	1.489	0.685
		5	1.489	0.380
		6	1.575	0.713
	4	1	1.775	0.000
		2	1.363	0.000
		3	1.489	0.685
		5	1.450	0.996
		6	1.538	1.000
	5	1	1.775	0.000
		2	1.363	0.000
		3	1.489	0.380
		4	1.450	0.996
		6	1.538	0.998
	6	1	1.848	0.000
		2	1.457	0.000
		3	1.575	0.713
		4	1.538	1.000
		5	1.538	0.998
Max force	1	2	74.031	0.243
		3	78.468	0.000
		4	77.054	0.000
		5	77.054	0.000
		6	80.200	0.000
	2	1	74.031	0.243
		3	61.003	0.000
		4	59.173	0.000
		5	59.173	0.000
		6	63.216	0.000
	3	1	78.468	0.000
		2	61.003	0.000
		4	64.638	0.799
		5	64.638	0.774
		6	68.358	0.738
	4	1	77.054	0.000
		2	59.173	0.000
		3	64.638	0.799
		5	62.914	1.000
		6	66.730	1.000
	5	1	77.054	0.000
		2	59.173	0.000
		3	64.638	0.774
		4	62.914	1.000
		6	66.730	1.000
	6	1	80.200	0.000
		2	63.216	0.000
		3	68.358	0.738
		4	66.730	1.000
		5	66.730	1.000
Sustained duration	1	2	9.682	1.000
		3	10.263	0.561
		4	10.078	0.704
		5	10.078	0.579
		6	10.489	0.832
	2	1	9.682	1.000
		3	7.979	0.458
		4	7.739	0.635
		5	7.739	0.470
		6	8.268	0.822
	3	1	10.263	0.561
		2	7.979	0.458
		4	8.454	1.000
		5	8.454	1.000
		6	8.941	0.996
	4	1	10.078	0.704
		2	7.739	0.635
		3	8.454	1.000

		5	8.228	1.000
		6	8.728	1.000
	5	1	10.078	0.579
		2	7.739	0.470
		3	8.454	1.000
		4	8.228	1.000
		6	8.728	0.998
	6	1	10.489	0.832
		2	8.268	0.822
		3	8.941	0.996
		4	8.728	1.000
		5	8.728	0.998
IMF sustained	1	2	9.065	0.436
		3	9.608	0.956
		4	9.435	1.000
		5	9.435	1.000
		6	9.820	0.935
	2	1	9.065	0.436
		3	7.469	0.852
		4	7.245	0.153
		5	7.245	0.154
		6	7.740	0.918
	3	1	9.608	0.956
		2	7.469	0.852
		4	7.914	0.852
		5	7.914	0.852
		6	8.370	1.000
	4	1	9.435	1.000
		2	7.245	0.153
		3	7.914	0.852
		5	7.703	1.000
		6	8.171	0.811
	5	1	9.435	1.000
		2	7.245	0.154
		3	7.914	0.852
		4	7.703	1.000
		6	8.171	0.811
	6	1	9.820	0.935
		2	7.740	0.918
		3	8.370	1.000
		4	8.171	0.811
		5	8.171	0.811
FMF sustained	1	2	10.371	1.000
		3	10.993	0.522
		4	10.795	0.429
		5	10.795	0.349
		6	11.236	0.891
	2	1	10.371	1.000
		3	8.546	0.121
		4	8.290	0.071
		5	8.290	0.046
		6	8.856	0.534
	3	1	10.993	0.522
		2	8.546	0.121
		4	9.056	1.000
		5	9.056	1.000
		6	9.577	0.978
	4	1	10.795	0.429
		2	8.290	0.071
		3	9.056	1.000
		5	8.814	1.000
		6	9.349	0.949
	5	1	10.795	0.349
		2	8.290	0.046
		3	9.056	1.000
		4	8.814	1.000
		6	9.349	0.901
	6	1	11.236	0.891
		2	8.856	0.534
		3	9.577	0.978
		4	9.349	0.949

		5	9.349	0.901
IMF-FMF sustained	1	2	8.668	0.609
		3	9.188	0.051
		4	9.022	0.288
		5	9.022	0.213
		6	9.391	0.233
	2	1	8.668	0.609
		3	7.143	0.429
		4	6.929	0.968
		5	6.929	0.913
		6	7.402	0.917
	3	1	9.188	0.051
		2	7.143	0.429
		4	7.569	0.899
		5	7.569	0.957
		6	8.004	0.974
	4	1	9.022	0.288
		2	6.929	0.968
		3	7.569	0.899
		5	7.367	1.000
		6	7.814	1.000
	5	1	9.022	0.213
		2	6.929	0.913
		3	7.569	0.957
		4	7.367	1.000
		6	7.814	1.000
	6	1	9.391	0.233
		2	7.402	0.917
		3	8.004	0.974
		4	7.814	1.000
		5	7.814	1.000
Hz/sec sustained	1	2	0.156	0.526
		3	0.166	0.484
		4	0.163	0.852
		5	0.163	0.893
		6	0.170	0.880
	2	1	0.156	0.526
		3	0.129	1.000
		4	0.125	0.988
		5	0.125	0.972
		6	0.134	0.989
	3	1	0.166	0.484
		2	0.129	1.000
		4	0.137	0.969
		5	0.137	0.945
		6	0.144	0.973
	4	1	0.163	0.852
		2	0.125	0.988
		3	0.137	0.969
		5	0.133	1.000
		6	0.141	1.000
	5	1	0.163	0.893
		2	0.125	0.972
		3	0.137	0.945
		4	0.133	1.000
		6	0.141	1.000
	6	1	0.170	0.880
		2	0.134	0.989
		3	0.144	0.973
		4	0.141	1.000
		5	0.141	1.000
Intermittent duration	1	2	47.112	0.966
		3	49.935	1.000
		4	49.036	0.985
		5	49.036	0.741
		6	51.038	0.928
	2	1	47.112	0.966
		3	38.821	0.992
		4	37.657	1.000
		5	37.657	0.968
		6	40.229	1.000

	3	1	49.935	1.000
		2	38.821	0.992
		4	41.135	0.998
		5	41.135	0.799
		6	43.502	0.970
	4	1	49.036	0.985
		2	37.657	1.000
		3	41.135	0.998
		5	40.037	0.951
		6	42.466	0.999
	5	1	49.036	0.741
		2	37.657	0.968
		3	41.135	0.799
		4	40.037	0.951
		6	42.466	0.998
	6	1	51.038	0.928
		2	40.229	1.000
		3	43.502	0.970
		4	42.466	0.999
		5	42.466	0.998
IMF intermittent	1	2	9.806	0.643
		3	10.394	0.963
		4	10.207	0.999
		5	10.207	1.000
		6	10.623	0.915
	2	1	9.806	0.643
		3	8.081	0.964
		4	7.838	0.172
		5	7.838	0.344
		6	8.374	0.995
	3	1	10.394	0.963
		2	8.081	0.964
		4	8.562	0.701
		5	8.562	0.884
		6	9.055	1.000
	4	1	10.207	0.999
		2	7.838	0.172
		3	8.562	0.701
		5	8.334	0.999
		6	8.839	0.577
	5	1	10.207	1.000
		2	7.838	0.344
		3	8.562	0.884
		4	8.334	0.999
		6	8.839	0.786
	6	1	10.623	0.915
		2	8.374	0.995
		3	9.055	1.000
		4	8.839	0.577
		5	8.839	0.786
FMF intermittent	1	2	10.663	0.969
		3	11.302	1.000
		4	11.099	0.612
		5	11.099	0.927
		6	11.552	1.000
	2	1	10.663	0.969
		3	8.787	0.980
		4	8.523	0.041
		5	8.523	0.241
		6	9.105	0.988
	3	1	11.302	1.000
		2	8.787	0.980
		4	9.310	0.294
		5	9.310	0.739
		6	9.846	1.000
	4	1	11.099	0.612
		2	8.523	0.041
		3	9.310	0.294
		5	9.062	0.972
		6	9.612	0.302
	5	1	11.099	0.927

		2	8.523	0.241
		3	9.310	0.739
		4	9.062	0.972
		6	9.612	0.735
	6	1	11.552	1.000
		2	9.105	0.988
		3	9.846	1.000
		4	9.612	0.302
		5	9.612	0.735
IMF-FMF intermittent	1	2	5.652	0.841
		3	5.990	0.894
		4	5.882	0.199
		5	5.882	0.550
		6	6.123	0.784
	2	1	5.652	0.841
		3	4.657	1.000
		4	4.517	0.629
		5	4.517	0.981
		6	4.826	1.000
	3	1	5.990	0.894
		2	4.657	1.000
		4	4.935	0.668
		5	4.935	0.979
		6	5.219	1.000
	4	1	5.882	0.199
		2	4.517	0.629
		3	4.935	0.668
		5	4.803	0.966
		6	5.094	0.863
	5	1	5.882	0.550
		2	4.517	0.981
		3	4.935	0.979
		4	4.803	0.966
		6	5.094	0.999
	6	1	6.123	0.784
		2	4.826	1.000
		3	5.219	1.000
		4	5.094	0.863
		5	5.094	0.999
Hz/sec intermittent	1	2	0.044	0.997
		3	0.047	0.979
		4	0.046	0.547
		5	0.046	0.900
		6	0.048	0.998
	2	1	0.044	0.997
		3	0.036	0.999
		4	0.035	0.596
		5	0.035	0.970
		6	0.038	1.000
	3	1	0.047	0.979
		2	0.036	0.999
		4	0.039	0.862
		5	0.039	0.999
		6	0.041	1.000
	4	1	0.046	0.547
		2	0.035	0.596
		3	0.039	0.862
		5	0.038	0.969
		6	0.040	0.706
	5	1	0.046	0.900
		2	0.035	0.970
		3	0.039	0.999
		4	0.038	0.969
		6	0.040	0.982
	6	1	0.048	0.998
		2	0.038	1.000
		3	0.041	1.000
		4	0.040	0.706
		5	0.040	0.982
Systolic BP before contraction	1	2	6.420	0.936
		3	6.805	0.073

		4	6.682	0.206
		5	6.682	0.024
		6	6.955	0.001
	2	1	6.420	0.936
		3	5.290	0.151
		4	5.132	0.444
		5	5.132	0.040
		6	5.482	0.001
	3	1	6.805	0.073
		2	5.290	0.151
		4	5.606	0.987
		5	5.606	0.997
		6	5.928	0.390
	4	1	6.682	0.206
		2	5.132	0.444
		3	5.606	0.987
		5	5.456	0.864
		6	5.787	0.113
	5	1	6.682	0.024
		2	5.132	0.040
		3	5.606	0.997
		4	5.456	0.864
		6	5.787	0.639
	6	1	6.955	0.001
		2	5.482	0.001
		3	5.928	0.390
		4	5.787	0.113
		5	5.787	0.639
Systolic BP after sustained	1	2	9.765	0.961
		3	10.351	0.222
		4	10.164	0.594
		5	10.164	0.056
		6	10.579	0.003
	2	1	9.765	0.961
		3	8.047	0.396
		4	7.805	0.891
		5	7.805	0.079
		6	8.339	0.002
	3	1	10.351	0.222
		2	8.047	0.396
		4	8.526	0.957
		5	8.526	0.979
		6	9.017	0.352
	4	1	10.164	0.594
		2	7.805	0.891
		3	8.526	0.957
		5	8.299	0.601
		6	8.802	0.062
	5	1	10.164	0.056
		2	7.805	0.079
		3	8.526	0.979
		4	8.299	0.601
		6	8.802	0.747
	6	1	10.579	0.003
		2	8.339	0.002
		3	9.017	0.352
		4	8.802	0.062
		5	8.802	0.747
Difference of systolic BP (sustained)	1	2	7.973	1.000
		3	8.451	0.995
		4	8.298	1.000
		5	8.298	0.927
		6	8.637	0.792
	2	1	7.973	1.000
		3	6.570	0.999
		4	6.373	1.000
		5	6.373	0.936
		6	6.808	0.768
	3	1	8.451	0.995
		2	6.570	0.999
		4	6.961	0.995

		5	6.961	0.996
		6	7.362	0.945
	4	1	8.298	1.000
		2	6.373	1.000
		3	6.961	0.995
		5	6.776	0.899
		6	7.187	0.715
	5	1	8.298	0.927
		2	6.373	0.936
		3	6.961	0.996
		4	6.776	0.899
		6	7.187	0.998
	6	1	8.637	0.792
		2	6.808	0.768
		3	7.362	0.945
		4	7.187	0.715
		5	7.187	0.998
Diastolic BP before contraction	1	2	4.726	0.926
		3	5.009	0.288
		4	4.919	0.067
		5	4.919	0.001
		6	5.120	0.025
	2	1	4.726	0.926
		3	3.894	0.621
		4	3.777	0.145
		5	3.777	0.001
		6	4.036	0.050
	3	1	5.009	0.288
		2	3.894	0.621
		4	4.126	0.966
		5	4.126	0.152
		6	4.364	0.760
	4	1	4.919	0.067
		2	3.777	0.145
		3	4.126	0.966
		5	4.016	0.527
		6	4.260	0.991
	5	1	4.919	0.001
		2	3.777	0.001
		3	4.126	0.152
		4	4.016	0.527
		6	4.260	0.909
	6	1	5.120	0.025
		2	4.036	0.050
		3	4.364	0.760
		4	4.260	0.991
		5	4.260	0.909
Diastolic BP after sustained	1	2	7.764	0.947
		3	8.229	1.000
		4	8.081	0.878
		5	8.081	0.448
		6	8.411	0.486
	2	1	7.764	0.947
		3	6.398	0.977
		4	6.206	1.000
		5	6.206	0.791
		6	6.630	0.826
	3	1	8.229	1.000
		2	6.398	0.977
		4	6.779	0.921
		5	6.779	0.432
		6	7.169	0.486
	4	1	8.081	0.878
		2	6.206	1.000
		3	6.779	0.921
		5	6.598	0.942
		6	6.998	0.951
	5	1	8.081	0.448
		2	6.206	0.791
		3	6.779	0.432
		4	6.598	0.942

		6	6.998	1.000
	6	1	8.411	0.486
		2	6.630	0.826
		3	7.169	0.486
		4	6.998	0.951
		5	6.998	1.000
Difference of diastolic (sustained)	1	2	7.046	0.999
		3	7.469	0.865
		4	7.334	0.982
		5	7.334	0.963
		6	7.634	1.000
	2	1	7.046	0.999
		3	5.806	0.436
		4	5.632	0.771
		5	5.632	0.676
		6	6.017	0.987
	3	1	7.469	0.865
		2	5.806	0.436
		4	6.152	0.994
		5	6.152	0.999
		6	6.507	0.893
	4	1	7.334	0.982
		2	5.632	0.771
		3	6.152	0.994
		5	5.988	1.000
		6	6.352	0.993
	5	1	7.334	0.963
		2	5.632	0.676
		3	6.152	0.999
		4	5.988	1.000
		6	6.352	0.981
	6	1	7.634	1.000
		2	6.017	0.987
		3	6.507	0.893
		4	6.352	0.993
		5	6.352	0.981
HR before contraction	1	2	6.963	0.282
		3	7.380	0.007
		4	7.247	0.105
		5	7.247	0.118
		6	7.543	0.068
	2	1	6.963	0.282
		3	5.738	0.269
		4	5.565	0.972
		5	5.565	0.982
		6	5.946	0.884
	3	1	7.380	0.007
		2	5.738	0.269
		4	6.079	0.756
		5	6.079	0.718
		6	6.429	0.936
	4	1	7.247	0.105
		2	5.565	0.972
		3	6.079	0.756
		5	5.917	1.000
		6	6.276	0.999
	5	1	7.247	0.118
		2	5.565	0.982
		3	6.079	0.718
		4	5.917	1.000
		6	6.276	0.998
	6	1	7.543	0.068
		2	5.946	0.884
		3	6.429	0.936
		4	6.276	0.999
		5	6.276	0.998
HR after sustained	1	2	7.442	0.286
		3	7.888	0.005
		4	7.745	0.099
		5	7.745	0.060
		6	8.062	0.082

	2	1	7.442	0.286
		3	6.132	0.212
		4	5.948	0.965
		5	5.948	0.882
		6	6.354	0.918
	3	1	7.888	0.005
		2	6.132	0.212
		4	6.497	0.704
		5	6.497	0.846
		6	6.871	0.863
	4	1	7.745	0.099
		2	5.948	0.965
		3	6.497	0.704
		5	6.324	1.000
		6	6.708	1.000
	5	1	7.745	0.060
		2	5.948	0.882
		3	6.497	0.846
		4	6.324	1.000
		6	6.708	1.000
	6	1	8.062	0.082
		2	6.354	0.918
		3	6.871	0.863
		4	6.708	1.000
		5	6.708	1.000
Difference of HR after sustained	1	2	4.442	1.000
		3	4.708	0.993
		4	4.624	0.999
		5	4.624	0.970
		6	4.812	1.000
	2	1	4.442	1.000
		3	3.660	0.997
		4	3.551	1.000
		5	3.551	0.976
		6	3.793	1.000
	3	1	4.708	0.993
		2	3.660	0.997
		4	3.879	1.000
		5	3.879	1.000
		6	4.102	0.998
	4	1	4.624	0.999
		2	3.551	1.000
		3	3.879	1.000
		5	3.775	0.993
		6	4.004	1.000
	5	1	4.624	0.970
		2	3.551	0.976
		3	3.879	1.000
		4	3.775	0.993
		6	4.004	0.982
	6	1	4.812	1.000
		2	3.793	1.000
		3	4.102	0.998
		4	4.004	1.000
		5	4.004	0.982
Sys BP after intermittent	1	2	9.888	0.981
		3	10.481	0.306
		4	10.292	0.631
		5	10.292	0.037
		6	10.712	0.003
	2	1	9.888	0.981
		3	8.148	0.444
		4	7.904	0.857
		5	7.904	0.031
		6	8.444	0.001
	3	1	10.481	0.306
		2	8.148	0.444
		4	8.634	0.982
		5	8.634	0.863
		6	9.131	0.204
	4	1	10.292	0.631

		2	7.904	0.857
		3	8.634	0.982
		5	8.403	0.426
		6	8.913	0.040
	5	1	10.292	0.037
		2	7.904	0.031
		3	8.634	0.863
		4	8.403	0.426
		6	8.913	0.795
	6	1	10.712	0.003
		2	8.444	0.001
		3	9.131	0.204
		4	8.913	0.040
		5	8.913	0.795
Difference of systolic BP (Intermittent)	1	2	8.952	1.000
		3	9.488	1.000
		4	9.317	1.000
		5	9.317	0.885
		6	9.697	0.785
	2	1	8.952	1.000
		3	7.376	1.000
		4	7.155	1.000
		5	7.155	0.791
		6	7.644	0.648
	3	1	9.488	1.000
		2	7.376	1.000
		4	7.816	1.000
		5	7.816	0.938
		6	8.266	0.847
	4	1	9.317	1.000
		2	7.155	1.000
		3	7.816	1.000
		5	7.607	0.804
		6	8.069	0.668
	5	1	9.317	0.885
		2	7.155	0.791
		3	7.816	0.938
		4	7.607	0.804
		6	8.069	1.000
	6	1	9.697	0.785
		2	7.644	0.648
		3	8.266	0.847
		4	8.069	0.668
		5	8.069	1.000
Diastolic BP after intermittent	1	2	6.203	0.943
		3	6.574	1.000
		4	6.456	0.845
		5	6.456	0.124
		6	6.719	0.012
	2	1	6.203	0.943
		3	5.111	0.896
		4	4.958	0.101
		5	4.958	0.001
		6	5.296	0.000
	3	1	6.574	1.000
		2	5.111	0.896
		4	5.416	0.700
		5	5.416	0.035
		6	5.727	0.002
	4	1	6.456	0.845
		2	4.958	0.101
		3	5.416	0.700
		5	5.271	0.534
		6	5.591	0.064
	5	1	6.456	0.124
		2	4.958	0.001
		3	5.416	0.035
		4	5.271	0.534
		6	5.591	0.807
	6	1	6.719	0.012
		2	5.296	0.000

		3	5.727	0.002
		4	5.591	0.064
		5	5.591	0.807
Difference of diastolic BP (intermittent)	1	2	6.220	0.579
		3	6.593	0.567
		4	6.474	0.919
		5	6.474	0.985
		6	6.739	0.898
	2	1	6.220	0.579
		3	5.126	1.000
		4	4.972	0.973
		5	4.972	0.843
		6	5.312	0.024
	3	1	6.593	0.567
		2	5.126	1.000
		4	5.431	0.960
		5	5.431	0.826
		6	5.744	0.033
	4	1	6.474	0.919
		2	4.972	0.973
		3	5.431	0.960
		5	5.286	0.999
		6	5.607	0.175
	5	1	6.474	0.985
		2	4.972	0.843
		3	5.431	0.826
		4	5.286	0.999
		6	5.607	0.341
	6	1	6.739	0.898
		2	5.312	0.024
		3	5.744	0.033
		4	5.607	0.175
		5	5.607	0.341
HR after intermittent	1	2	7.657	0.313
		3	8.116	0.005
		4	7.970	0.141
		5	7.970	0.018
		6	8.295	0.042
	2	1	7.657	0.313
		3	6.310	0.174
		4	6.120	0.985
		5	6.120	0.503
		6	6.539	0.721
	3	1	8.116	0.005
		2	6.310	0.174
		4	6.686	0.561
		5	6.686	0.985
		6	7.071	0.958
	4	1	7.970	0.141
		2	6.120	0.985
		3	6.686	0.561
		5	6.507	0.906
		6	6.902	0.974
	5	1	7.970	0.018
		2	6.120	0.503
		3	6.686	0.985
		4	6.507	0.906
		6	6.902	1.000
	6	1	8.295	0.042
		2	6.539	0.721
		3	7.071	0.958
		4	6.902	0.974
		5	6.902	1.000
Difference of HR (intermittent)	1	2	4.066	1.000
		3	4.309	0.953
		4	4.232	1.000
		5	4.232	0.434
		6	4.405	0.955
	2	1	4.066	1.000
		3	3.350	0.964
		4	3.250	1.000

		5	3.250	0.295
		6	3.472	0.967
	3	1	4.309	0.953
		2	3.350	0.964
		4	3.550	0.961
		5	3.550	0.847
		6	3.754	1.000
	4	1	4.232	1.000
		2	3.250	1.000
		3	3.550	0.961
		5	3.455	0.328
		6	3.665	0.964
	5	1	4.232	0.434
		2	3.250	0.295
		3	3.550	0.847
		4	3.455	0.328
		6	3.665	0.868
	6	1	4.405	0.955
		2	3.472	0.967
		3	3.754	1.000
		4	3.665	0.964
		5	3.665	0.868
Initial half relaxation time	1	2	0.020	1.000
		3	0.021	1.000
		4	0.021	0.999
		5	0.021	0.999
		6	0.022	0.921
	2	1	0.020	1.000
		3	0.017	0.993
		4	0.016	1.000
		5	0.016	0.987
		6	0.017	0.698
	3	1	0.021	1.000
		2	0.017	0.993
		4	0.018	0.975
		5	0.018	1.000
		6	0.019	0.960
	4	1	0.021	0.999
		2	0.016	1.000
		3	0.018	0.975
		5	0.017	0.961
		6	0.018	0.617
	5	1	0.021	0.999
		2	0.016	0.987
		3	0.018	1.000
		4	0.017	0.961
		6	0.018	0.967
	6	1	0.022	0.921
		2	0.017	0.698
		3	0.019	0.960
		4	0.018	0.617
		5	0.018	0.967
Final half relaxation time	1	2	0.027	0.993
		3	0.028	0.946
		4	0.028	1.000
		5	0.028	1.000
		6	0.029	0.960
	2	1	0.027	0.993
		3	0.022	0.452
		4	0.021	0.998
		5	0.021	0.977
		6	0.023	0.524
	3	1	0.028	0.946
		2	0.022	0.452
		4	0.023	0.760
		5	0.023	0.892
		6	0.024	1.000
	4	1	0.028	1.000
		2	0.021	0.998
		3	0.023	0.760
		5	0.023	1.000

		6	0.024	0.808
	5	1	0.028	1.000
		2	0.021	0.977
		3	0.023	0.892
		4	0.023	1.000
		6	0.024	0.920
	6	1	0.029	0.960
		2	0.023	0.524
		3	0.024	1.000
		4	0.024	0.808
		5	0.024	0.920
Half relaxation time change	1	2	0.016	0.979
		3	0.017	0.871
		4	0.017	1.000
		5	0.017	0.999
		6	0.017	1.000
	2	1	0.016	0.979
		3	0.013	0.208
		4	0.013	0.919
		5	0.013	0.999
		6	0.014	0.908
	3	1	0.017	0.871
		2	0.013	0.208
		4	0.014	0.796
		5	0.014	0.459
		6	0.015	0.871
	4	1	0.017	1.000
		2	0.013	0.919
		3	0.014	0.796
		5	0.014	0.993
		6	0.015	1.000
	5	1	0.017	0.999
		2	0.013	0.999
		3	0.014	0.459
		4	0.014	0.993
		6	0.015	0.989
	6	1	0.017	1.000
		2	0.014	0.908
		3	0.015	0.871
		4	0.015	1.000
		5	0.015	0.989