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Influence of mobility and daily activity on low-threshold EMG in older women

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INFLUENCE OF MOBILITY AND DAILY ACTIVITY ON LOW-THRESHOLD EMG IN OLDER WOMEN

by

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DECLARATION OF PREVIOUS PUBLICATION

I. Co-Authorship Declaration

I hereby declare that this thesis incorporates material that is the result of joint research, as follows: Sara H. Bruce collected, analyzed and developed the manuscript while working under the supervision of Jennifer M. Jakobi and in collaboration with Gareth. R. Jones. This work was funded by grants from Dr's Jakobi and Jones. The collaboration is covered in Chapter 3 of the thesis.

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I certify that, with the above qualification, this thesis, and the research to which it refers, is the product of my own work.

II. Declaration of Previous Publication

This thesis includes one original paper that has been previously submitted for publication in a peer reviewed journal, as follows:

Thesis Chapter	Publication title/full citation	Publication status
Chapter 3	*Influence of Instrumental Activities of Daily Living in Long Term EMG Recordings*	*Submitted for publication*

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ABSTRACT

Increases in low threshold EMG may occur as a consequence of mobility or daily activity. The purpose of this study was to determine whether mobility (ambulation and life-space movement) or activities of daily living influence low-threshold EMG in older women (>75 years). EMG was examined in upper and lower body muscles for an 8-hour day and compared with assessments of mobility from Global Positioning Systems and pedometers. Although mobility scores did not differ between groups, community-dwelling women reported higher instrumental activities of daily living compared with retirement-dwelling. EMG burst activity was ~25% greater and gap activity ~45% less in retirement-dwellers. Upper extremity muscles had ~45% greater number and rate of bursts and gaps than lower extremity muscles. On and off cycle of low threshold EMG in upper extremities and higher burst and lower gap activity in retirement-dwelling women likely occurs because EMG is sensitive to instrumental activities of daily living.

DEDICATION

This project is dedicated to all of the volunteers who donated their time. Specifically Helen Simpson, who graciously volunteered multiple times to ensure this project would run smoothly for all other participants. Your kindness and keen interest in furthering science will not be forgotten.

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GLOSSARY

Activities of Daily Living (ADL) - Normal daily activities required for independent living, including self-reliance (see IADL) and self-care tasks (see BADL).

Ambulation - A form of independent walking (without a gait aid).

Basic Activities of Daily Living (BADL) - Fundamental self-care activities (personal hygiene, feeding, dressing, toileting, transferring, continence).

Burst - A period of muscle activation above 2% of maximal muscle activity for longer than 0.1 seconds.

Community-dwellers - Individuals who reside independently in their community.

Daily Activity - Accumulation of all (ADL, recreational, exercise, caretaking etc.) physical activity over the recording period.

Disability - A physical or health problem lasting six months or more that may limit daily tasks.

Disability Free Life Expectancy - The predicted number of years an individual can function within society following birth without disability.

Gap - A period of muscle quiescence below 1% of maximal muscle activity for longer than 0.1 seconds.

Global Positioning System (GPS) - A satellite receiver unit that triangulates the location of the unit on the surface of the earth from time differentials of orbiting satellites to the unit.

Instrumental Activities of Daily Living (IADL) - Self-reliance activities (managing money, shopping, telephone use, travel in community, housekeeping, preparing meals, and taking medications correctly) often performed by a person who is living independently in a community setting during the course of a normal day. Increasing inability to perform IADL may result in the need for care facility placement.

Life expectancy – The average number of predicted years expected to live following birth.

Life Space Movement - The movement of an individual within their environment by either ambulatory or vehicular movement and quantified by distance explored from principle residence.

Mobility - The act of moving through personal life-space by either independent ambulation or vehicular travel.

Motor Unit - One alpha motor neuron and all of the muscle fibres that are innervated.

Pedometer - Unit which records ambulatory movement as step counts.

Physical Activity - Any movement of skeletal muscle above the resting levels.

Retirement Home - Facility providing individual rooms or apartments for housing in conjunction with à la carte services such as meals, housekeeping, laundry and social activities.

Sarcopenia - The loss of muscle mass associated with aging.

Surface Electromyography (EMG) - Muscle activity underlying an active electrode that is representing an entire muscle.

CHAPTER I
REVIEW OF LITERATURE

1.0 Aging in Canada

In Canada, since 2001 the population of oldest older-adult (>80 years of age) has increased 25%. In 2006, one in seven Canadians was 65 years or older, and of this demographic, one in four older adults were 80 years or older (Statistics Canada, 2007). This group of older adults continue to increase at a faster rate relative to all other Canadian age cohorts (Health Canada, 2001). In part, this increase in the cohort of older adults is due to an increased life expectancy in Canada, which has risen in the last fifty years from 68.6 years to 77.9 years. Currently, the life expectancy for Canadian men is approximately 78 years and for Canadian women is approximately 83 years (St-Arnaud, Beaudet, Tully & Tully, 2005; Statistics Canada).

It is important to note that the reported life expectancy values are not representative of a “disability free existence”. Disability free life expectancy refers to the numbers of years that an individual can function within society without disability (Gilmour & Park, 2004). A disability is defined as a physical or health problem lasting six months or more that may limit daily tasks and pursuits (Gilmour & Park). Typical daily tasks can be segmented into two categories: functional tasks and non-functional tasks. Both functional and non-functional tasks are integral aspects of typical daily activity and quality of life of older adults (Jette, 2005). Non-functional tasks include social activities (such as socializing with friends and family) and leisure activities (such as participating in sports, gardening or artistic pursuits). Functional tasks, often described as Activities of Daily Living (ADL), range from activities that are required for personal independence such as bathing and feeding, to those not required for personal independence such as driving or housework. Functional tasks required for self-reliance are called instrumental activities of daily living (IADL), while self-care tasks are called basic activities of daily living (BADL). Examples of IADL include shopping for groceries, housework or preparing meals. Tasks of personal care such as eating, dressing and daily hygiene are BADL. Often, BADL and IADL are determinant factors of functional independence, or the loss therein (Gilmour & Park). The interrelationship between the two with respect to functional independence might be demonstrated, for example as an individual who can no longer independently purchase groceries and consequential to the loss of the IADL the BADL for self-care through nutritious meals is additionally affected. The key factor differentiating a BADL from an IADL is the ability of an older adult to maintain an independent lifestyle; loss of BADL not the IADL inevitably equates to loss of functional independence (Trottier, Martel, Houle, Berthelot, & Legare, 2000). The disassociation and categorization of tasks as BADL and IADL occurs in an identical manner for all older adults, regardless of whether they reside independently in the community or within a care facility. Identifying tasks as BADL and IADL is integral for evaluating the level of independence maintained by an older adult irrespective of the living environment (Trottier et al., 2000).

The Ontario Ministry of Health defines three types of older adult residential care facilities: supportive housing, retirement facilities and long-term care facilities (Ontario Ministry of Health and Long Term Care, 2007). These care facilities can be separated based upon the level of services and living assistance that may be provided. The first form of older adult housing, supportive housing, provides the fewest number of services. Supportive housing provides residents independent apartments with rent-geared-to-income. Personal care workers may be available and meals and social events may be provided. Individuals who choose to live in supportive housing do not require immediate or 24 hour nursing care. At the other end of the assisted living spectrum, long-term care homes provide a furnished room for residents who require 24 hour nursing and personal care. On site supervision is also available for the personal safety of residents.

In contrast, retirement facilities provide residents individual rooms or apartments, typically unfurnished. Unlike supportive housing, retirement facilities provide services such as meals and social activities, but also provide a living environment that is adaptable to the needs of the residents over time. This includes housekeeping, laundry, recreational and rehabilitation services on an 'as per need' basis. Retirement facilities are appropriate for individuals who do not require 24 hour nursing care or specialized health services. Of the three options, retirement facilities offer the greatest variety of services but the focus of the services is directed towards maintaining the independence of residents.

Many individuals residing in retirement facilities (retirement-dwelling) are able to live independently within the community, but choose this living environment for social or security reasons. Security and services in a retirement facility range from minimal to high. The scope of services offered range from partial assistance (housekeeping) to complete support (cooking, bathing). These services are available and may change on an individual basis when need increases. Thus, older adults living in retirement facilities today are more heterogeneous than traditionally observed. As a consequence, previous categorization of retirement-dwelling older adults as dependent, and community-dwelling older adults as independent, is no longer accurate (Dallosso et al., 1988). Retirement-dwelling older adults may be of similar health and physical ability relative to community-dwelling older adults; however, they are likely to be less physically active due to services provided.

Older adults who opt for any level of assistance, but are capable, may functionally decline at a faster rate relative to older adults who care for themselves independently. This occurs regardless of whether they live in the community or within a retirement facility. Although age associated increases in chronic health conditions may contribute to dependence, the decrease in physical activity that occurs as a result of assisted living may have a far greater impact. For example, muscle weakness, and cardiorespiratory decline are not only associated with aging, but also physical inactivity (Paterson, Govindasamy, Vidmar, Cunningham, & Koval, 2004). This in turn contributes to declines in ADL and inevitably functional dependence whereby, women in particular are at a greater risk of becoming dependant relative to men (Fried & Guralnik, 1997).

Physical inactivity and female sex are directly associated with physical decline leading to dependence (Guralnik, Ferrucci, Simonsick, Salive, & Wallace, 1995). Older women account for 43% of total health care expenditures of older adults associated with loss of independence (Health Canada, 2002). Thus, there is an increased need to better understand functional decline in women in order to prolong independence. Sixty-five percent of individuals who are in the oldest old age grouping (+85 years of age), are women (Statistics Canada, 2007). These women live with a greater number of chronic conditions than men of the same age and with greater need for assistance due to inability to perform ADL (Crimmins, Saito, & Ingegneri, 1989; 1997; Wolf, 1995). Increased morbidity with concomitant longevity predispose older women to be placed into a residential care facility, rather than remain within the care of their immediate family because the number of persons within the family unit has decreased and unlike prior generations the number of women in the work force is higher (Wolf).

1.1 Physiological Changes Associated with Functional Decline

Each additional year of life after 70 years of age increases the probability of dependence by 22% (Paterson et al., 2004). Although chronic health conditions often predispose functional loss, other age-related physiological adaptations which can be slowed also contribute to functional decline. These physiological age adaptations, such as loss of muscle mass, strength and power are often exacerbated by declines in physical activity levels performed daily (Dipietro, 2001). Westerterp and Meijer (2001) reported that older adults have significantly less fat free mass and more body fat than younger adults, and suggested that the changes found in fat free mass are a result of a loss of muscle mass. The loss of muscle mass associated with aging is identified as sarcopenia (Evans & Campbell, 1993). Sarcopenia is commonly associated with a decrease in muscle strength and power (Frontera et al., 2000; Galea, 1996; Lindle et al., 1997) and has a consequent effect on ambulation and mobility (Rosenberg, 1997). Lexell (1997) suggests the predominant cause of the changes in muscle with age is a loss in size and number of type II muscle fibres.

The greater change in type II fibres is predominantly due to the age associated loss of large diameter alpha motor neurons. A muscle fibre can only be innervated by one alpha motor neuron, but one alpha motor neuron can innervate many fibres. Thus, a motor unit is composed of one alpha motor neuron and all of the fibres that it innervates. Large alpha motor neurons innervate type II or fast twitch fibres; whereas small diameter alpha motor neurons innervate type I or slow fibres. When an alpha motor neuron dies, its associated fibres are orphaned. In relation to aging, the orphaned muscle fibres are typically type II and may be subsumed by small alpha motor neurons. This adoption of type II fibres by small alpha motor neurons causes the type II fibres to exhibit type I behaviours. As a consequence of adopting these fibres, the size of the motor unit increases, albeit there are now fewer motor units (Galea, 1996). This process of motor neuron loss and re-innervation of muscle fibres is known as age-related motor unit remodelling. Decreases in number of motor units is apparent at ~65 years, increases dramatically after the age of 80 years and seems to become functionally relevant in the ninth decade (McNeil, Doherty, Stashuk, & Rice, 2006). Older adults (aged 60-70 years) perform approximately 20-40% lower on strength tests compared with younger adults and the oldest old exhibit greater declines of ~50% or more compared with younger adults (Vandervoort, 2002; Vandervoort & McComas, 1986). Sedentary individuals can lose an additional 20-40% of their muscle mass as they age (Singh, 2002). As well, in women, loss of strength typically occurs at the onset of menopause (Carville, Rutherford, & Newham, 2006), when decreases in estrogen production may increase the rate of sarcopenia (Poehlman, Toth, & Gardner, 1995). As women frequently demonstrate lower strength measures than men throughout the life span, any decline in strength may have a greater effect upon strength-related ADL in women compared with men, such as transferring oneself from bed to a chair (Boyd Foster-Burns, 1999; Lexell, 1995).

Strength decrements have been found to be greater in the lower limbs compared with the upper extremities (Frontera, Hughes, Lutz, & Evans, 1991; Lynch et al., 1999). Onder et al. (2002) reported this differential to be greater in women 80 years of age or older compared with women 65-79 years of age. It was suggested that these differences were due to a greater decrease in the use of the lower limbs compared with the upper limbs. Guralnik et al. (1995) observed that a decrease in lower extremity function was significantly related to limitations in ADL performance such as repeatedly rising from a chair and a standing balance task. Sarcopenia-related muscle weakness has also been strongly associated with diminished gait speed, poor balance, and falls in older adult women (Porter, Vandervoort, & Lexell, 1995). Specific muscles are also associated with ADL performance. The soleus and gastrocnemius were positive indicators for the ability to perform ADL (Posner et al., 1995). The stronger the muscles (as measured by a one repetition maximum), the greater the ADL score (as measured by self report scales). Because women have less muscle mass than men, (approximately 40-60% less) they are at a greater risk of becoming dependent (Frontera et al.).

An increase in physical activity has been associated with reducing the rate of decline in ADL. The ability to perform an ADL is also known in the literature as a functional ability or conversely, a functional limitation. Miller, Rejeski, Reboussin, Ten Have, and Ettinger (2000) observed that older individuals who were moderately physically active (walked a minimum of one mile a week) reported fewer functional limitations 5-years after initial measures. In general, individuals who were moderately active were less likely to develop functional limitations as compared with sedentary individuals (Wu, Leu, & Li, 1999) and older adults participating in vigorous physical activity were only half as likely to develop limitations in ADL compared with sedentary peers (Leveille, Guralnik, Ferrucci, & Langlois, 1999). Overall, an increase in the number of hours of physical activity performed per week slows the decline of functional limitations associated with aging (Buchman, Boyle, Wilson, Bienias, & Bennett, 2007).

1.2 Technology for Long Term Evaluation of Physical Activity

Although a worldwide consensus supports the need for older adults to become more active (Paterson et al., 2004), objective measurements of daily activities are difficult to acquire and may not be representative of real-life. Most studies that investigate the physiological mechanisms associated with changes to functional performance have been confined to a controlled laboratory setting which does not take into consideration the environmental constraints and situations in which daily activities precipitate. For example, ambulation in the laboratory does not include side walk cracks, or hills, and chair rises do not incorporate ‘noise’ such as conversation and television. Alternatively, self-report questionnaires, as well as clinical or home observation are often utilized; however, they are unrepresentative of daily activities due to recall bias and insensitivity to incidental daily walking behaviours of participants (Ainsworth, Leon, Richardson, Jacobs, & Paffenbarger, 1993; Richardson, Leon, Jacobs, Ainsworth, & Serfass, 1993; Sallis & Saelens, 2000; Uswatte et al., 2000). Overall, questionnaires and observation are less than ideal for measuring physical activity. Advances in technology have enabled the design of tools to offer minimally obtrusive monitoring of movements in a variety of settings. Most importantly, these devices provide measures outside of a laboratory or clinic permitting participants to pursue ‘typical’ daily activities.

1.3 Accelerometers & Pedometers

Pedometers and accelerometers are tools that enable quantitative measurement of dynamic movement (Bassett et al., 1996). Although both tools record movement by detection of accelerations or by motion and impact of the body through space, there are several reasons why many researchers choose to use a pedometer when investigating physical ambulation. First, accelerometers tend to be more expensive than pedometers, which unfortunately is a frequent and relevant factor in how research is conducted. Second, accelerometers are a more complex motion sensor that provides considerable information, often in excess of what is needed to assess movement. Accelerometers record movement and rotation. The unit may be uniaxial, biaxial or triaxial, meaning one to all three planes of movement are recorded. Thus, as the hips sway, a person sits down, or rotates to reach an object, the accelerometer detects movement, which in turn may be misinterpreted as ambulation (Westerepp, 1999). In contrast, pedometers are limited to detecting movement in one plane.

Pedometer output is a tally of daily step counts (ambulatory movement), with no extensions to the intensity of the activity. Pedometers measure upright ambulation through absolute counts or steps associated with each heel strike. Thus, in assessing upright ambulation, pedometers are the most objective tool, whereas more complex calculations that are intensity driven are best undertaken with accelerometers. There is a correlation between these two tools in free-living conditions (r = 0.80-0.90), but only when the output of both tools is expressed as raw data (i.e. steps/day or activity counts rather than distance travelled or energy expended) (Bassett, Cureton, & Ainsworth, 2000; Tudor Locke & Meyers, 2001).

Electronic pedometers utilize three basic mechanisms for recording: a spring-suspended horizontal lever arm, a glass-enclosed magnetic reed proximity switch or a horizontal beam and a piezoelectric crystal (Crouter, Schneider, Karabulut, & Bassett, 2003). The simplistic design of modern pedometers also allows for a lower manufacturing cost than accelerometers and requires no additional technical expertise for use and enhances broad based population use (Schneider, Crouter, Lukajic, & Bassett, 2003; Tudor-Locke & Myers, 2001). This tool is used in settings where a researcher is not present, for instance, long term projects where subjects must maintain a daily log of total steps taken. In such studies, each morning participants would be required to place the unit over the midline of the thigh and zero the step counter. This ease in set-up promotes multiple observations with little experimenter intervention. Pedometers are more accurate than self-report questionnaires where male and female participants typically under-report daily walking distances (Bassett et al., 2000).

The reliability and validity of pedometers as a mobility tool has been evaluated by a variety of researchers. It has been found that this tool is appropriate for collecting data related to ambulation. Bassett et al. (1996) compared the accuracy of five pedometers while walking on a paved sidewalk, a rubber track and a treadmill at varying velocities. The pedometers were found to be accurate within 11% of the total distance travelled whether on pavement or rubberized track. Crouter et al. (2003) found pedometers to generally be most accurate for measuring number of steps taken as compared to distance travelled.

However, pedometers typically underestimate number of steps taken and overestimate distances travelled at slower speeds (between 54 and 67 m/min). Conversely, at faster speeds, (>80 m/min) pedometers tend to underestimate distances but the actual steps taken are accurate within ±1%. As discussed in Le Masurier and Tudor-Locke (2003), the underestimation of steps at slower speeds may be a problem when evaluating frail older adults with slow gait (< 60 m/min). Older adults within long term care facilities are also more likely to walk slower and have gait impairments (Cyarto, Myers, & Tudor-Locke, 2004); and, walking speeds in controlled investigations are typically much slower than self-selected walking speeds typical of many healthy older adults and these contribute to pedometer inaccuracy (Hendelman, Miller, Baggett, Debold, & Freeson, 2000). However, different gait speeds between individuals is likely not a significant source of error in studies of free-living activity where walking speed is self-selected. Overall, pedometers are not perfect tools to determine absolute ambulation, but when used regularly within individuals or between groups, an overall indication of the extent of upright ambulation can be readily gained.

1.4 Global Positioning System

Global Positioning Systems (GPS) are a new tool available for the evaluation of daily activity. Current research has looked at using this equipment in a variety of settings including; free range animals such as dairy cattle (Ganskopp & Johnson, 2007), during sport related activities (Larsson, 2003; Larsson & Henriksson-Larsen, 2001; Witte & Wilson, 2005), automobile driving in older adults (Marshall et al., 2007), individuals in urban settings (Duncan, Mummery, & Dascombe, 2007), and as a gait or locomotion analysis tool (Frank & Patla, 2003; Schutz & Herren, 2000; Terrier, Ladetto, Merminod, & Schutz, 2001; Terrier & Schutz, 2005). Accessibility and affordability of this tool has increased general use and application of GPS measures.

A GPS unit works by receiving signals from satellites orbiting around the earth. These satellites send information regarding time to the unit which is then compared to the internal time of the unit. The signal time can then be calculated as well as the distance to the satellite. A comparison of the data between three satellites by a trigonometric calculation provides the location of the unit relative to the surface of the earth (Duncan et al., 2007; Larsson, 2003; Larsson & Henriksson-Larsen, 2001). Original designs of these units were not compact and had limited general use. Modern GPS units are more portable, less obtrusive and are cost effective compared with units previously available (Schutz & Herren, 2000; Terrier, Ladetto, Merminod, & Schutz, 2000; Witte & Wilson, 2005). In the past, GPS units would be worn inside a small backpack (Terrier et al., 2000; Witte & Wilson). Current GPS models range from the size of a cellular phone to an oversized wrist watch (Duncan et al.) and contain substantial memory capacity and battery life to record and collect data over time, such that long-term or daily studies may be performed (Rodriguez, Brown, & Troped, 2005). Researchers can now use GPS as a mobility tool to complement daily activity studies. This tool provides a measure of absolute distance the unit travels whether a person or machine enabled the change in geographical position.

In general, pedometry, and GPS have enhanced the ability to measure movement within one's life-space. These tools offer minimally obtrusive monitoring in a variety of settings, but most importantly, these devices can be utilized outside of the laboratory while pursuing 'typical' daily routines. The key to successful use of these tools is appropriate application of the measurement obtained. Pedometers score absolute upright ambulatory movement through recording number of steps taken, while GPS provides an indication of movement through one's life-space irrespective of the method of mobility (independent ambulation versus machine assisted movement). To gain an indication of physical activity, pedometers should be used to reflect individual ambulation and GPS should be used to provide gross life-space movement. Thus, these tools can be used in conjunction to provide information relative to physical activity and physical independence.

An individual may have a high GPS life-space movement score of distance travelled, which would suggest physical independence in the environment; however, this physical independence may correspond to lower levels of ambulation which would be indicated by a low pedometer score. For example, a community-dwelling individual who spent a significant period of time driving, but had minimal ambulation is still mobile within their life-space. While an individual in a retirement facility may remain in one geographic location for a significant period but frequently ambulate between rooms of other residents. Such an individual would be ambulatory but with a limited life-space. Thus, to clearly understand mobility, GPS and pedometer should be used. Together, these tools will help to distinguish older adults who are mobile from those who are not, regardless of living environment or mode of mobility (ambulatory or vehicular). Identifiable boundaries of mobility can be indicated by life-space categorization (Peel et al., 2005). Division of an individual's living environment is based upon the primary residence (usually the area where sleeping takes place), and expanding outwards into zones whereby the individual ambulates or travels by vehicle. The zones may be identified as; remaining within the residence, remaining within property boundaries, remaining within the surrounding neighbourhood, remaining within the boundaries of the community. The GPS unit is able to indicate whether or not an individual remains within their primary residence, and subsequent to leaving the ‘home’ is able to geographically map which zones of life-space are travelled. Dissociation of types of mobility is becoming more advanced, but neither GPS nor pedometers provide an indication of the muscle activity that underlies movement. Portable electromyography (EMG) devices may provide this additional insight.

1.5 Surface Electromyography

Surface electromyography (EMG) is a non-invasive means to record electrical activity of muscle, whereby electrodes are placed over the muscle of interest. Electrodes are attached to the skin of the participant and do not pierce the skin. The measure obtained is a global representation of the activity of all of the muscle fibres underlying the active electrode. As such, EMG is used as a comprehensive measure of whole muscle activity, but the actual potentials of the signal are gained only from the recording area under the electrode (Farina, Merletti, & Enoka, 2004). Surface EMG is the most commonly used measure of muscle activity because it is a non-invasive recording of muscle activity; however, these signals do not indicate specific muscle characteristics such as fibre phenotype, genotype, strength, or cross sectional area.

Traditionally surface EMG testing was performed in a laboratory setting where participants were asked to execute muscle specific tasks. Most frequently, isometric contractions were undertaken, but with advances in technology muscle activity can be readily acquired for dynamic contractions with considerable ease and accuracy. Most recently, EMG has been utilized outside the laboratory with portable devices to evaluate long-term activity of individuals in the workplace and in daily activity (Jakobi, Edwards, & Connelly, 2008; Kern, Semmler, & Enoka, 2001; Mork & Westgaard, 2005; Nordander et al., 2000). Jakobi et al. (2008) were the first to utilize this tool to measure muscle activity in healthy younger and older adults, and older adults post-stroke while they pursued typical daily activities. This work suggested that portable EMG does not impede typical daily routines in healthy younger and older adults, or in people with co-morbidities such as stroke.

The reliability of this device over testing periods of several hours and between different test sessions has been established. Ochia and Cavanagh (2006) evaluated the reliability of 12 hour recordings of EMG from both upper and lower extremity muscles. Results from the data collection indicated that EMG values evaluated over smaller time periods (ten second epochs) were consistent over the duration of the total testing period. Kern et al. (2001) also compared recordings collected over an 8 hour day and reported that values collected over different weekdays were consistent for the vastus lateralis, vastus medialis, biceps brachii and first dorsal interosseus in young adults ($p > 0.01$). Rather than using the standard methods of reporting EMG as an integrated and normalized variable, bursts in the signal were determined.

Bursts and gaps represent the temporal characteristics of electrical activity underlying muscle contraction (Monster, Chan, & O'Connor, 1978). Specifically, bursts represent a period of muscle activation above a threshold percentage of maximal activity whereas gaps represent a period of muscle quiescence below a threshold percentage of the same maximal activity (Harwood, Edwards, & Jakobi, 2008). Nordander et al. (2000) defined a burst as a period of EMG that was longer than 0.1 second and greater than 2% of the maximum EMG. Parallel to the determination of burst activity from EMG, calculation of gaps in the signal has been undertaken during evaluation of work tasks. A gap was quantified as a period of EMG that is less than 1% maximum and lasts for durations longer than 0.1 second. Subsequent to the determination of burst and gap number, the spatial (e.g. amplitude) and temporal (e.g. rate, duration) characteristics of individual bursts and gaps, and the population of bursts and gaps can be defined. The characterization of bursts and gaps in the signal lends itself to clarifying low-threshold EMG activity.

Laursen, Jensen, and Ratkevicius (2001) measured upper extremity muscle activity during computer mouse tasks in women 22-28 and 56-70 years of age. Older women had approximately double the muscle activity of younger women. The older women had approximately 18-22% EMG gaps (percentage of the total time) in the deltoid and both the right and left trapezius, whereas the younger women had approximately 28-50% gaps. This indicated that muscles of the older women were more active and resting less than the muscles in younger women. Thorn et al. (2007) also evaluated the muscle activity of the trapezius in older women (45-65 years of age) while performing different computer related tasks. Results indicated that individuals with self reported neck/shoulder injury demonstrated increased muscle activation and decreased muscle rest. This suggests that measures of low threshold EMG might be used to assess predisposition to injury, and as gap activity decreases with age, older adults might be more susceptible to muscle injury. When comparing upper to lower extremities, Kern et al. (2001) reported that irrespective of sex, the upper extremity was active approximately 18% of the recording time, whereas the lower extremity (quadriceps) was active approximately 10% of the recording time. However, the amplitudes of the lower extremity bursts were ~170% greater than the upper extremity bursts. Because lower extremity muscles are larger and stronger than upper extremity muscles (Beliaeff, Bouchard, Hautier, Brochu, & Dionne, 2008) the amplitude of the bursts might be associated with strength, whereas the amount of burst activity (percentage of recording time above threshold) may indicate muscle use.

Long-term recording of EMG from the trapezius during a typical work day of men and women reported differences in gap activity between cleaning and computer related jobs. Cleaning duties exhibited the fewest periods of gaps (approximately 1.5% of time below 3% the relative voluntary exertion) amongst all work related tasks. In contrast, computer related activities had approximately 11% muscle gaps. Additionally, differences in muscle activity between men and women were reported when performing the same tasks associated with a manufacturing job (Nordander et al., 2008). Women exhibited greater amounts of burst activity in the trapezius (18 ± 9.2 %MVE) and forearm extensors (39 ± 11%MVE) compared with men (12 ± 4.3 and 27 ± 10 %MVE, respectively). Kern et al. (2001) also found differences in burst duration between men and women in the biceps brachii for a 10 hour recording session of daily activity ($p < 0.05$). In general, muscle activity differences (for bursts and gaps) have been reported between men and women during different job tasks and over the course of a typical 10-hour day. The mechanism underlying differences between men and women, and the underlying source of burst and gap activity remains to be elucidated.

Burst and gap activity in young and old, men and women for an 8-hour non-work day suggests that in addition to sex-related differences, age-related differences in burst and gap activity are evident. For a typical 8-hour day burst duration and area increase, whereas gap duration and rate decrease in women compared with men and these sex differences increase with age (Jakobi et al., 2008) (Figure 1). To evaluate whether time of day or activities undertaken during a day, affect the burst and gap measures a standardized task was undertaken. Prior to, and following, a full 8-hour day of daily activity a discrete functional task of lifting, carrying and placing a weighted grocery bag was undertaken (Harwood et al., 2008). Low threshold burst and gap activity did not differ between the morning and evening sessions, indicating time of day and the activities undertaken during the day do not alter burst and gap activity. However, for the discrete task, older adults had approximately 3-7 times greater burst activity relative to younger adults and women were found to have a fewer number of bursts (7.9 ±1.0) compared with men (14.6 ± 0.7) in conjunction with greater burst duration and area (Harwood et al.). Differences between younger and older adults for burst and gap activity suggests that previously reported differences in muscle activity are not solely due to task differences.

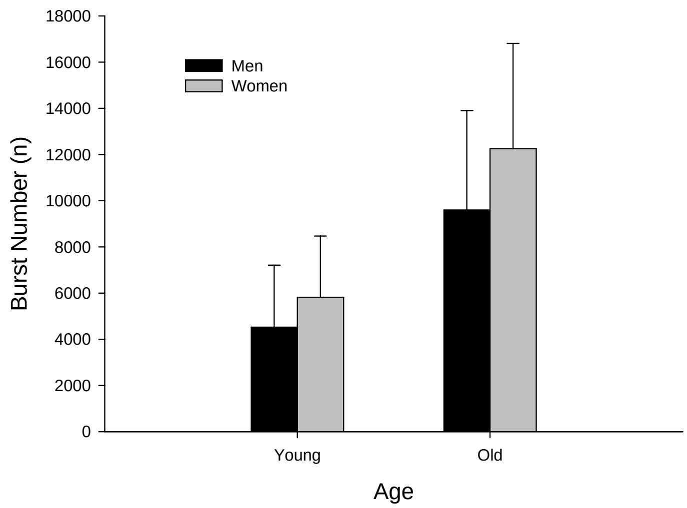

Figure 1. Age- and sex-related differences in EMG burst characteristic. Burst number increases with age and is greater in women compared with men. Adapted data from Jakobi, et al., 2008.

1.6 Underlying Cause of Age- and Sex-Related Change in Burst and Gaps

The age- and sex-related changes in low-threshold EMG are the first reports of plastic differences in muscle activity during real life outside controlled laboratory settings. The observations made to-date (Harwood et al., 2008; Jakobi et al., 2008) prompts questions of: 1) do these age- and sex-related changes in low-threshold EMG contribute to declines in functional independence or, 2) can these measures of low-threshold EMG activity be utilized to assess older adults to better predict loss of functional independence? However, in order to address the global question of the use of portable EMG in the assessment of functional independence, the mechanisms underlying the age- and sex-related increases in burst activity and decreases in gap activity must be defined. The alterations in low threshold EMG might result from ‘life’ factors (mobility, tasks undertaken) or physiological characteristics (strength, fatigue, neural strategies) (Figure 2).

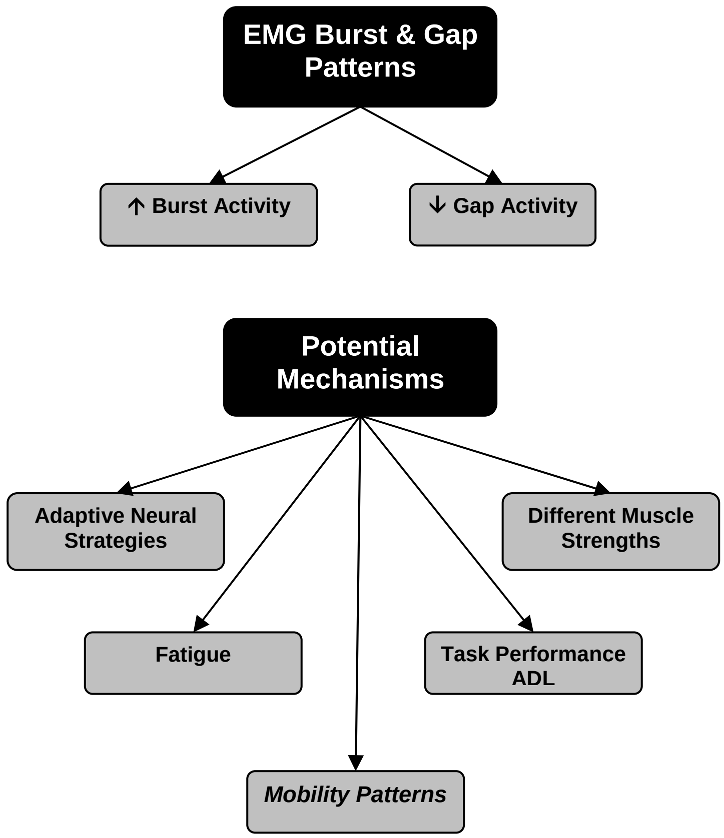

Figure 2. Age associated changes in muscle EMG patterns. Burst activity has been found to increase with age whereas gap activity decreases. Potential mechanisms for the reported changes include; adaptive neural strategies, different muscle strengths, fatigue, task performance or mobility pattern of participants.

The EMG signal is a compilation of all muscle fibres from active motor units underlying the surface electrode. A variety of laboratory studies offer insight into how changes within muscle, fatigue, or strength, influence burst and gap characteristics of EMG. Age-related motor unit remodelling and a decrease in motor unit discharge rates are well reported (Vandervoort, 2002) and it is likely that changes in motor unit activity influence burst and gap activity. Muscle fatigue influences the EMG signal obtained in controlled laboratory tasks (McNeil et al., 2006; Porter et al., 1995) and induces alteration in the pattern of on- and off-cycles of bursts relative to time to fatigue (Rudroff, Christou, Poston, Bojsen-Moller, & Enoka, 2007). Burst activity may be associated with changes in muscle strength from exercise training, or decline in muscle mass associated with inactivity or immobilization (Semmler, Kutzscher, & Enoka, 2000). These controlled laboratory studies provide an indication of some of the possible underlying physiological causes of age- and sex-related changes in low-threshold EMG (Figure 2). Additionally, real-world factors may influence low-threshold EMG. Previously, Harwood et al. (2008) employed a specific discrete task and determined that burst activity increases and gap activity decreases with increased age and in women. This study indicated that sex- and age-related increases in low-threshold EMG were still evident when the task performed is discrete and identical between groups. Because the sex- and age-related changes were still evident, but smaller than what had been observed over 8-hour recordings, there are additional factors contributing to the differences. It is also possible that mobility or ADL will influence low-threshold EMG (Figure 2). The greatest strength of portable EMG is the ability to record over extensive durations, without being tethered to a computer, while undertaking typical activities of daily living. Yet, this strength is also a weakness. There is no exact means with EMG to determine daily activities that are being undertaken. Although activity diaries provide some indication, they are unable to provide exact measures of physical activity levels or mobility patterns. Using questionnaires, physical activity monitors such as pedometers to gain a measure of steps taken, and GPS to assess life-space movement, while measuring muscle activity with portable EMG will enable determination of whether daily activity is an underlying cause of age- and sex-related change in low threshold EMG.

1.7 References

Ainsworth, B. E., Leon, A. S., Richardson, M. T., Jacobs, D. R., & Paffenbarger, R. S. (1993). Accuracy of the college alumnus physical activity questionnaire. *Journal of Clinical Epidemiology, 46,* 1403-1411.

Bassett, D. R., Ainsworth, B. E., Leggett, S. R., Mathien, C. A., Main, J. A., Hunter, D. C., et al. (1996). Accuracy of five electronic pedometers for measuring distance walked. *Medicine & Science in Sports & Exercise, 28*, 1071-1077.

Bassett, D. R., Cureton, A. L., & Ainsworth, B. E. (2000). Measurement of daily walking distance-questionnaire versus pedometer. *Medicine & Science in Sports & Exercise, 32*, 1018-1023.

Beliaeff, S., Bouchard, D. R., Hautier, C., Brochu, M., & Dionne, I. J. (2008). Association between muscle mass and isometric strength in well-functioning older men and women. *Journal of Aging and Physical Activity, 16,* 484-493.

Boyd Foster-Burns, S. (1999). Sarcopenia and decreased muscle strength in the elderly woman: Resistance training and a safe and effective intervention. *Journal of Women & Aging, 11*, 75-85.

Buchman, A. S., Boyle, P. A., Wilson, R. S., Bienias, J. L., & Bennett, D. A. (2007). Physical activity and motor decline in older persons. *Muscle & Nerve, 35,* 354-362.

Carville, S. F., Rutherford, O. M., & Newham, D. J. (2006). Power output, isometric strength, and steadiness in the leg muscles of pre- and postmenopausal women: The effect of hormone replacement therapy. *European Journal of Applied Physiology, 96,* 292-298.

Crimmins, E. M., Saito, Y., & Ingegneri, D. (1989). Changes in life expectancy and disability-free life expectancy in the United States. *Population and Development Review, 15,* 235-267.

Crimmins, E. M., Saito, Y., & Ingegneri, D. (1997). Trends in disability-free life expectancy in the United States, 1970-1990. *Population Development and Review, 23,* 555-572.

Crouter, S. E., Schneider, P. L., Karabulut, M., & Bassett, D. R. (2003). Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. *Medicine & Science in Sports & Exercise, 35*, 1455-1460.

Cyarto, E. V., Myers, A. M., & Tudor-Locke, C. (2004). Pedometer accuracy in nursing homes and community–dwelling older adults. *Medicine & Science in Sports & Exercise, 36*, 205-209.

Dallosso, H. M., Morgan, K., Bassey, e. J., Ebrahim, S. B., Fentem, P. H. & Arie, T. H. (1988). Levels of customary physical activity among the old and very old living at home. *Journal of Epidemiology and Community Health, 42,* 121-127.

DiPietro, L. (2001). Physical activity in aging: Changes in patterns and their relationship to health and function. *Journal of Gerontology Series A: Biological Sciences and Medical Sciences, 56A,* 13-22.

Duncan, M. J., Mummery, W. K., & Dascombe, B. J. (2007). Utility of global positioning system to measure active transport in urban areas. *Medicine & Science in Sports & Exercise, 39*, 1851-1857.

Evans, W. J., & Campbell, W. W. (1993) Sarcopenia and age-related changes in body composition and functional capacity. *The Journal of Nutrition, 123*, 454-458.

Farina, D., Merletti, R., & Enoka, R. M. (2004). The extraction of neural strategies from surface EMG. *Journal of Applied Physiology, 96,* 1486-1495.

Frank, J. S., & Patla, A. E. (2003). Balance and mobility challenges in older adults: Implications for preserving community mobility. *American Journal of Preventative Medicine, 25,* 157-163.

Fried, L. P., & Guralnik, J. M. (1997). Disability in older adults: Evidence regarding significance, etiology, and risk. *Journal of the American Geriatrics Society, 45*, 92-100.

Frontera, W. R., Hughes, V. A., Fielding, R. A., Fiatarone, M. A., Evans, W. J., & Roubenoff, R. (2000). Aging of skeletal muscle: A 12-yr longitudinal study. *Journal of Applied Physiology, 88,* 1321–1326.

Frontera, W. R., Hughes, V. A., Lutz, K. J., & Evans, W. J. (1991). A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women. *Journal of Applied Physiology, 71,* 644–650.

Ganskopp, D. C., & Johnson, D. D. (2007). GPS error in studies addressing animal movements and activities. *Rangeland Ecology & Management, 60*, 350-358.

Galea, V. (1996). Changes in motor unit estimates with aging. *Journal of Clinical Neurophysiology, 13,* 253-60.

Gilmour, H., & Park, J. (2004). Dependency, chronic conditions and pain in seniors. *Health Reports* (Statistics Canada Catalogue No. 82-003). *16,* 21-31.

Guralnik, J. M., Ferrucci, L., Simonsick, E. M., Salive, M. E., & Wallace, R. B. (1995). Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *The New England Journal of Medicine, 339*, 556- 561.

Harwood, B., Edwards, D. L., & Jakobi, J. M. (2008). Age- and sex-related differences in muscle activation for a discrete functional task. *European Journal of Applied Physiology, 103,* 677-686.

Health Canada. (2001). *Canada's seniors... at a glance.* Retrieved April 20, 2009, from http://www.phac-aspc.gc.ca/seniors-aines/index_ pages/publications_e.htm.

Health Canada. (2002). *Canada's aging population* (Catalogue No. H39-608/2002E). Ottawa, ON: Ministry of Public Works and Government Services.

Hendelman, D., Miller, K., Baggett, C., Debold, E., & Freeson, P. (2000). Validity of accelerometry for the assessment of moderate intensity physical activity in the field. *Medicine & Science in Sports & Exercise, 32*, 442-450.

Jakobi, J. M., Edwards, D. L., & Connelly, D. M. (2008). Utility of portable electromyography for quantifying muscle activity during daily use. *Gerontology, 54*, 324-331.

Jette, A. M. (2005). Assessing disability in studies on physical activity. *American Journal of Preventative Medicine, 25,* 122-128.

Kern, D. S., Semmler, J.G., & Enoka, R. M. (2001). Long-term activity in upper and lower-limb muscles of humans. *Journal of Applied Physiology, 91,* 2224–2232.

Larsson, P. (2003). Global positioning system and sport-specific testing. *Sports Medicine, 33*, 1093-1101.

Larsson, P., & Henriksson-Larsen, K. (2001). The use of dGPS and simultaneous metabolic measurements during orienteering. *Medicine & Science in Sports & Exercise, 33*, 1919-1924.

Laursen, B., Jensen, B. R., & Ratkevicius, A. (2001). Performance and muscle activity during computer mouse tasks in young and elderly adults. *European Journal of Applied Physiology, 84,* 329-336.

Le Masurier, G. C., & Tudor-Locke, C. (2003). Comparison of pedometer and accelerometer accuracy under controlled conditions. *Medicine & Science in Sports & Exercise, 35*, 867-871.

Leveille, S. G., Guralnik, J. M., Ferrucci, L., & Langlois, J. A. (1999). Aging successfully until death in old age: opportunities for increasing active life expectancy. *American Journal of Epidemiology, 149,* 654–664.

Lexell, J. (1995). Human aging, muscle mass, and fiber type composition. *The Journals of Gerontology, 50A*, 11-16.

Lexell, J. (1997). Evidence for nervous system degeneration with advancing age. *The Journal of Nutrition, 127*, 1011-1013.

Lindle, R. S., Metter, E. J., Linch, N. A., Fleg, J. L., Fozard, J. L., Tobin, J., et al. (1997). Age and gender comparisons of muscle strength in 654 women and men aged 20-93 years. *Journal of Applied Physiology, 83,* 1581-1587.

Lynch, N. A., Metter, E. J., Lindle, R. S., Fozard, J. L., Tobin, J. D., Roy, T. A., et al. (1999). Muscle quality. I. Age-associated differences between arm and leg muscle groups. *Journal of Applied Physiology, 86,* 188 –194.

Marshall, S. C., Wilson, K. G., Molnar, F. J., Man-Son-Hing, M., Steill, I., & Porter, M. M. (2007). Measurement of driving patterns of older adults using data logging devices with and without global positioning system capability. *Traffic Injury Prevention, 8,* 260-266.

McNeil, C. J., Doherty, T. J., Stashuk, D. W., & Rice, C. L. (2006). Motor unit number estimates in the tibialis anterior muscle of young, old, and very old men. *Muscle & Nerve, 31,* 461-467.

Miller, M. E., Rejeski, W. J., Reboussin, B. A., Ten Have, T. R., & Ettinger, W. H. (2000). Physical activity, functional limitations, and disability in older adults. *Journal of the American Geriatrics Society*, 48, 1264–1272.

Monster, A. W., Chan, H C. & O'Connor, D. (1978). Activity patterns of human skeletal muscles: Relation to muscle fiber type composition. *Science, 200*, 314-317.

Mork, P. J., & Westgaard, R. H. (2005). Long-term electromyographic activity in the trapezius and low back muscles of women with moderate physical activity. *Journal of Applied Physiology, 99,* 570-578.

Nordander, C., Hansson, G. A., Rylander, L., Asterland, P., Bystrom, J. U., Ohlsson, K., et al. (2000). Muscular rest and gap frequency as EMG measures of physical exposure: The impact of work tasks and individual related factors. *Ergonomics, 43*, 1904-1919.

Nordander, C., Ohlsson, K., Balogh, I., Hansson, G. A., Axmon, A., Persson, R., et al. (2008). Gender differences in workers with identical repetitive industrial tasks: Exposure and musculoskeletal disorders. *International Archives of Occupational and Environmental Health, 81,* 939-947.

Ochia, R. S., & Cavanagh, P. R. (2006). Reliability of surface EMG measurements over 12 hours. *Journal of Electromyography and Kinesiology, 17*, 365-371.

Onder, G., Penninx, B. W. J. H., Lapuerta, P., Freid, L. P., Ostir, G. V., Guralnik, J. M., et al. (2002). Change in physical performance over time in older women: The women's health and aging study. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 57A*, 289-293.

Ontario Ministry of Health and Long Term Care. (2007). *Seniors' care: Residences offering care.* Retrieved November 16th, 2008, from http://www.health.gov.on.ca/english/public/program/ltc/12_residential_mn.html

Paterson, D. H., Govindasamy, D., Vidmar, M., Cunningham, D. A., & Koval, J. J. (2004). Longitudinal study of determinants of dependence in an elderly population. *Journal of the American Geriatrics Society, 52*, 1632-1638.

Peel, C., Sawyer-Baker, P., Roth, D. L., Brown, C. J., Bodner, E. V., & Allman, R. M. (2005). Assessing mobility in older adults: The UAB study of aging life-space assessment. *Physical Therapy. 85*, 1008-1019.

Poehlman, E., Toth, M. J., & Gardner, A. W. (1995). Changes in energy balance and body composition at menopause: A controlled longitudinal study. *Annals of Internal Medicine, 123*, 673-675.

Porter, M. M., Vandervoort, A. A., & Lexell, J. (1995). Aging of human muscle: Structure, function and adaptability. *Scandinavian Journal of Medicine & Science in Sports, 5,* 129–142.

Posner, J. D., McCully, K. K., Landsberg, L. A., Sands, L., Tycenski, P., Hofmann, M., et al. (1995). Physical determinants of independence in mature women. *Archives of Physical Medicine & Rehabilitation*, *76,* 373–380.

Richardson, M. T., Leon, A. S., Jacobs, D. R., Ainsworth, B. E., & Serfass, R. (1993). Comprehensive evaluation of the Minnesota Leisure Time Physical Activity Questionnaire. *Journal of Clinical Epidemiology, 47,* 271-281.

Rodriguez, D. A., Brown, A. L., & Troped, P. J. (2005). Portable global positioning units to complement accelerometry-based physical activity monitors. *Medicine & Science in Sports & Exercise, 37*, 572-581.

Rosenberg, I. H. (1997). Sarcopenia: Origins and clinical relevance. *The Journal of Nutrition, 127*, 990-991.

Rudroff, T., Christou, E. A., Poston, B., Bojsen-Moller, J., & Enoka, R. M. (2007). Time to failure of a sustained contraction is predicted by target torque and intial electromyographic bursts in elbow flexors. *Muscle & Nerve, 35,* 657-666.

Sallis, J. F., & Saelens, B. E. (2000). Assessment of physical activity by self report: Status, limitations, and future directions. *Research Quarterly for Exercise & Sport, 71*, 1-14.

Schneider, P. L., Crouter, S. E., Lukajic, O., & Bassett, D. R. (2003). Accuracy and reliability of 10 pedometers for measuring steps over a 400-m walk. *Medicine & Science in Sports & Exercise, 35*, 1779-1784.

Schutz, Y., & Herren, R. (2000). Assessment of speed of human locomotion using a differential satellite global positioning system. *Medicine & Science in Sports & Exercise, 32*, 642-646.

Semmler, J. G., Kutzscher, D. V., & Enoka, R. M. (2000). Limb immobilization alters muscle activation patterns during a fatiguing isometric contraction. *Muscle & Nerve, 23,* 1381-1392.

Singh, M. A. F. (2002). Exercise comes of age: Rationale and recommendations for a geriatric exercise prescription. *Journal of Gerontology Series A: Biological and Medical Sciences, 57A*, 262-282.

St-Arnaud, J., Beaudet, M. P., Tully, B., & Tully, P. (2005). Life Expectancy. *Health Reports* (Statistics Canada Catalogue No. 82-003). *17*, 43-47.

Statistics Canada. (2007). *Portrait of the Canadian population in 2006, by age, and sex, 2006 census* (Statistics Canada Catalogue No. 97-551-XIE). Ottawa, ON: Ministry of Industry.

Terrier, P., Ladetto, Q., Merminod, B., & Schutz, Y. (2000). High-precision satellite positioning system as a new tool to study the biomechanics of human locomotion. *Journal of Biomechanics, 33,* 1717-1722.

Terrier, P., Ladetto, Q., Merminod, B., & Schutz, Y. (2001). Measurement of the mechanical power of walking by satellite positioning system (GPS). *Medicine & Science in Sports & Exercise, 33*, 1912-1918.

Terrier, P., & Schutz, Y. (2005). How useful is satellite positioning system (GPS) to track gait parameters? *Journal of NeuroEngineering and Rehabilitation, 2,* 28.

Thorn, S., Sogaard, K., Kallenberg, L. A. C., Sandsjo, L., Sjogaard, G., Hermens, H. J., et al. (2007). Trapezius muscle rest time during standardised computer work – A comparison of female computer users with and without self-reported neck/shoulder complaints. *Journal of Electromyography and Kinesiology, 17,* 420-427.

Trottier, H., Martel, L., Houle, C., Berthelot, J. M., & Legare, J. (2000). Living at home or in an institution: What makes the difference for seniors? *Health Reports* (Statistics Canada, Catalogue No. 82-003). *11,* 49-61.

Tudor-Locke, C. E., & Myers, A. M. (2001). Methodological considerations for researchers and practitioners using pedometers to measure physical (ambulatory) activity. *Research Quarterly for Exercise and Sport, 72*, 1-12.

Uswatte, G., Miltner, W. H. R., Foo, B., Varma, M., Moran, S., & Taub, E. (2000). Objective measurement of functional upper-extremity movement using accelerometer recordings transformed with a threshold filter. *Stroke, 31,* 662-667.

Vandervoort, A. A. (2002). Aging of the human neuromuscular system. *Muscle & Nerve, 25,* 17-25.

Vandervoort, A. A., & McComas, A. J. (1986). Contractile changes in opposing muscles of the human ankle joint with aging. *Journal of Applied Physiology, 61,* 361–367.

Westerterp, K. R. (1999). Physical activity assessment with accelerometers. *International Journal of Obesity, 23*, 45-49.

Westerterp, K. R., & Meijer, E. P. (2001). Physical activity and parameters of aging: A physiological perspective. *Journal of Gerontology Series A: Biological and Medical Sciences, 56A,* 7-12.

Witte, T. H., & Wilson, A. M. (2005). Accuracy of WAAS-enabled GPS for the determination of position and speed over ground. *Journal of Biomechanics, 38,* 1717-1722.

Wolf, D. A. (1995). Changes in living arrangements of older women: An international study. *The Gerontologist, 36,* 724-731.

Wu, S. C., Leu, S., & Li, C. (1999). Incidence of and predictors for chronic disability in activities of daily living among older people in Taiwan. *Journal of the American Geriatrics Society*, *47,* 1082–1086.

CHAPTER II

PURPOSE AND HYPOTHESES

2.0 Purpose

To determine whether mobility or living environment, which precipitates differences in physical activity, influences burst and gap activity in older adult women (>75 years of age). Women residing in a retirement facility were compared with independent community-dwelling older women. The biceps brachii, triceps brachii, vastus lateralis, and biceps femoris were monitored for a typical 8-hour day.

2.1 Specific Objectives

1. To record muscle activity with portable EMG in the biceps brachii, triceps brachii, vastus lateralis, and biceps femoris for a period of 8-hours in older women with different levels of mobility.
2. To measure mobility using pedometer and GPS in independent community-dwelling and retirement-dwelling older women.
3. To segregate the women by mobility based upon living environments and compare muscle EMG burst and gap activity between the two groups.
4. To evaluate levels of physical activity and ADL between the two groups.

2.2 Research Hypothesis

1. Subjects living in a retirement facility will show an increase in gap activity and a decrease in burst activity relative to community-dwelling subjects.
2. Mobility scores for GPS and pedometer in retirement-dwelling subjects will be lower compared with subjects living in the community.
3. Based upon availability of services, retirement-dwellers will be less physically active than women remaining in the community.
4. ADL will be greater in the community-dwelling compared with retirement-dwelling older women.

CHAPTER III
MANUSCRIPT

3.0 Introduction

Older adults (>65 years) are the fastest growing segment of the Canadian population, increasing to over 20% within the next decade and upwards of 30% within 20 years (Statistics Canada, 2007). Already, 91% of those 65+ years of age report one or more chronic diseases and 40% report significant disability (National Advisory Council on Aging, 2006). Age-related functional decline is often associated with reduced performance for activities of daily living (ADL) (Trottier, Martel, Houle, Berthelot, & Legare, 2000). Activities of daily living are comprised of both higher functioning, self-reliant instrumental activities of daily living (IADL) (Lawton & Brody, 1969) and the basic activities of daily living (BADL) required for self-care and hygiene (Katz, Down, Cash, & Grotz, 1970). In general, loss of any IADL precedes the BADL decline which results in functional dependence (Guralnik, Ferrucci, Simonsick, Salive, & Wallace, 1995). Maintenance of functional independence occurs through physical activity movements, including ADL, recreational activities and exercise, (Buchman, Boyle, Wilson, Bienias, & Bennett, 2007; Guralnik, et al., 1995; Miller, Rejeski, Reboussin, Ten Have, & Ettinger, 2000; Wu, Leu, and Li 1999). Simply, being an older female is a risk factor for loss of functional independence (Guralnik et al.) as older women are burdened with more chronic disease conditions relative to men (Crimmins, Saito, & Ingegneri, 1989; 1997; Wolf, 1995) which predisposes them to greater functional decline in old age (Guralnik et al.) and, in-turn, increased occupancy of residential-care facilities relative to men (Turcotte & Schellenberg, 2007).

Retirement facilities can provide a variety of services to assist older adults. Individual services provided can be detailed on a pay for service basis that centres upon the abilities and needs of each resident. The Ontario Ministry of Health defines retirement facilities as having individual rooms or apartments where services such as meals, social activities, and recreation/rehabilitation activities are provided on an "as per need basis" (Ontario Ministry of Health and Long Term Care, 2007). Generally, retirement-dwellers are older adults functioning at a higher level than individuals residing in long-term-care facilities, but because of the range of services provided, this population is quite heterogeneous and may range from functionally independent to those requiring assistance with some or all IADL. Individuals in this type of care facility execute all BADL; however, decline or inability to perform IADL may signal a transition whereby the older adult may have to move to a facility that provides more comprehensive care. Debate surrounds whether providing services foster a sense of ‘learned dependence’ by the residents which may eventually inhibit their ability to remain functionally independent (Johnson et al., 2005). The model of learned dependence in old age reflects the environmental conditions in which one inhabits (Baltes, 1995). For example, over time the resident living in a retirement facility may become more accepting of services that support IADL, thus, fostering reliance or dependency on these services, whereas the community-dwelling older adult is required to complete all IADL in order to remain functionally independent. However, it is not yet clear whether the availability of assistive services alters daily physical activity accumulation, since the provision of such services may allow for more time devoted towards recreational activities.

Physical activity is often difficult to measure in this population due to the complexity of health and environmental issues older adults face. As a result, there is no single tool available for the evaluation of physical activity in all older adults across all facets of mobility. Pedometers provide a measure of step counts acquired through upright ambulation (Bassett, Cureton, & Ainsworth, 2000) and global positioning system (GPS) receivers indicate gross life-space movement, irrespective of the mode of transportation (Duncan, Mummery, & Dascombe, 2007). Together, these tools help distinguish between older adults who are mobile from those who are not, regardless of living environment and with respect to mobility type (ambulatory and vehicular). Identifiable boundaries of mobility can be indicated through life-space categorization (Peel et al., 2005), which is the division of a subject's living environment into zones identified as; remaining within the residence, remaining within property boundaries, remaining within the surrounding neighbourhood, remaining within the boundaries of the community. Although, both measurement devices describe daily physical activity patterns at some level, they do not provide a measure of muscle activity that governs movement.

Electromyography (EMG) provides a quantifiable measurement of muscle activity during the performance of typical daily activities. The characteristics of EMG activity, bursts and gaps, represent muscle activation above and, muscle quiescence, below a threshold percentage of maximal activity (Harwood, Edwards & Jakobi, 2008). The underlying cause of increases in low-threshold EMG has yet to be identified. One potential factor may be mobility, which is associated with both ADL and functional independence. Therefore, the purpose of this investigation was to determine the influence of mobility and ADL on low-threshold EMG in women who reside in retirement-dwellings and women who live in the community.

3.1 Methods

Subjects

Twenty-three women (83 $\pm$ 5 years of age) were recruited to participate. Ten subjects resided in a retirement facility and thirteen subjects resided in the community. Recruitment was from the communities of Lanark County and the City of Ottawa in Eastern Ontario, Canada. Inclusion criteria included healthy women, older than 75 years of age, who were either living in the community or in a retirement facility. Exclusion criteria included uncontrolled blood pressure and/or diabetes, reliance on a gait aid (i.e. cane, walker), or surgical treatment within the past 6-months. All subjects were administered the Paffenbarger Physical Activity Questionnaire (Appendix C) and the Yale Physical Activity Survey for Older Adults (Appendix D). The Paffenbarger Activity Questionnaire quantified caloric expenditure of the subject during physical activities over the duration of 1-week (Paffenbarger, Blair, Min Lee, & Hyde, 1993), whereas the Yale Physical Activity Survey for Older Adults was used to calculate physical activity of older adults over a variety of intensities for typical daily activities. (Dipietro, Caspersen, Ostfeld, & Nadel, 1993; Kruskall, Campbell, & Evens, 2004). Physical activity and electromyography (EMG) data were collected over a single weekday that was representative of a typical day. All experimental procedures received approval from the University of Windsor Human Research Ethics Board and conformed to the Helsinki Declaration. Informed written consent was received prior to participation.

3.2 Experimental Protocol

Instrumentation

Surface recording electrodes were placed on the biceps brachii, triceps brachii, vastus lateralis and biceps femoris of the non-dominant limb to measure global muscle activity of these muscles by electromyography (EMG) for an 8-hour period of a typical weekday (Figure 3).

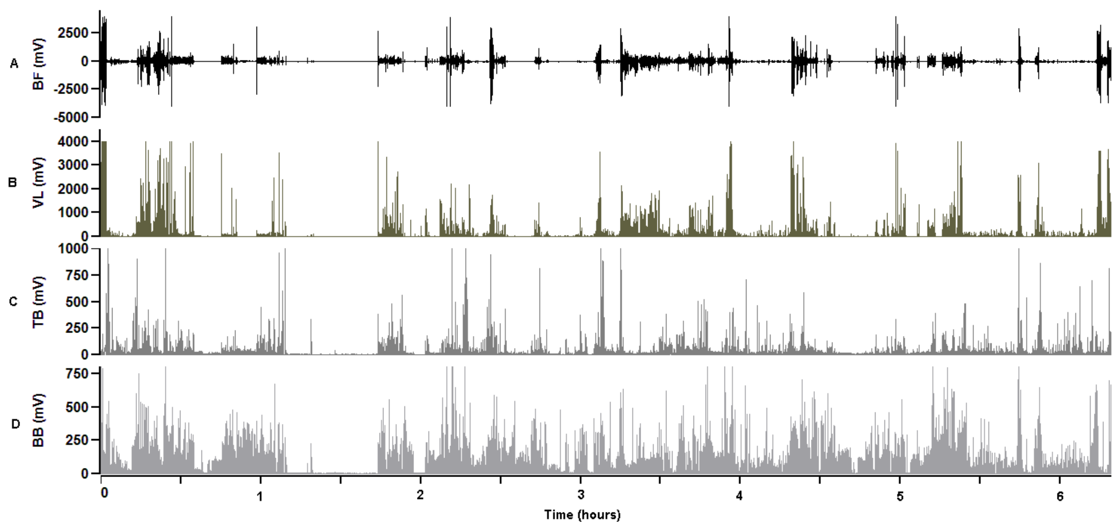

Figure 3. Representative recordings of surface EMG for the biceps femoris, vastus lateralis, triceps brachii, biceps brachii (top to bottom) for a community-dwelling older woman. A) Unprocessed surface EMG data. B) Rectified C) Rectified and smoothed D) Rectified, smoothed and down-sampled. BF, biceps femoris; VL, vastus lateralis; TB, triceps brachii; BB biceps brachii; mV, millivolts.

Electrode placement and attachment on all muscles was similar to prior studies (Harwood et al., 2008; Jakobi, Edwards, & Connelly, 2008). The electrodes on the biceps brachii, triceps brachii, vastus lateralis and biceps femoris were adhered to the mid-belly of the muscle with double sided medical die cut application tape (Biometrics T350) and Hypafix (Hamburg, Germany). Palpation of the muscle and functional testing of movement was used to ensure appropriate placement. The electrodes had an inter-electrode distance of 20mm, a built in gain (1000x), and band pass filter (20-450Hz) (Biometrics SX230, Gwent, UK). The common reference electrode (Biometrics Ground Reference R200) was placed on an area of boney prominence on the anterior aspect of the tibia on the same side as the recording electrodes, and attached by an adjustable strap. A high conductivity electrolyte gel (Microlyte, Pennsylvania, USA) was applied to ensure contact between the reference electrode and the subject's skin.

The common reference electrode and all recording electrodes were connected to a portable data logger (Biometrics DataLOG P3X8, Gwent, UK) which stored signals during data collection on a 512 MB MMC flashcard. This unit was attached to the subject's waist by an adjustable belt. The portable data logger had dimensions of 9.5 x 15.8 x 3.3 cm (width x height x depth) and a weight of 380 g. The weight of the electrode heads, double sided medical die cut application tape, Hypafix and gel were negligible. Data from the Biometrics unit was downloaded via a USB cable to a computer hard-drive and stored for subsequent analysis.

To monitor life-space movement within the environment, a global positioning system (GPS) (Garmin Forerunner 305, Olathe, USA), was attached to the subject's non-dominant arm at the wrist. The GPS had dimensions of 5.33 x 6.86 x 1.78 cm (width x height x depth) and a weight of 77 g. Data from the GPS was also transferred via USB connection (Garmin Forerunner 305, Olathe, USA) to a computer hard-drive for further analysis.

To record the number of steps taken a pedometer (Yamax Digi-Walker SW-200, Tokyo, Japan) was attached to the same belt that the subject wore; to support the portable data logger. The pedometer was placed in alignment with the hip of the non-dominant leg. The pedometer was light (21 g) and small (0.5 x 0.38 x 0.21 cm). The number of steps was measured in whole unit step counts.

The pedometer was sealed shut so that the subject was blinded to the recorded output values.

Procedure

The morning of data collection (~8-10am), subjects living in the retirement facility were asked to arrive at a designated testing room or common area within the facility. Subjects residing in the community were visited in their home by the investigator. The experimental procedure was explained and written informed consent obtained. Thereafter the physical activity questionnaires were administered (Paffenbarger Physical Activity Questionnaire, and Yale Physical Activity Survey for Older Adults).

Subsequent to GPS, pedometer and electrode placement three Maximal Voluntary Exertions (MVE) for each muscle of interest were performed and used as a baseline measure of maximal EMG output to facilitate the normalization of, the surface EMG recordings obtained during the 8-hour recording. The order in which the MVE were executed for each muscle was randomized, and the rest duration between each of the three attempts at an MVE within a muscle was 60 seconds to prevent fatigue. Maximal EMG was recorded against the investigator's manual resistance (Jakobi et al., 2008). All four muscle groups were tested with the subject seated. The chair was a standard armless chair with a firm high back and a seat of ~48cm. The biceps and triceps of the non-dominant arm were tested, with the arm slightly abducted and the elbow positioned to 90º. This position was maintained while a maximal elbow flexion (push up) or extension (push down) was conducted. The thigh muscles of the same side of the body were evaluated with the hip angle set at ~100 º and the knee positioned at 90º. This position was maintained during maximal flexion or extension of the knee. Consistent verbal encouragement was provided. All subjects were then asked to proceed with normal daily activities, but avoid any task that might damage the equipment or dislodge the electrodes such as bathing, swimming or strenuous exercise (Harwood et al., 2008; Jakobi et al.).

At the end of the day, approximately 8-9 hours later (~4-6pm), the subject was met and a final set of MVE were executed prior to removal of the testing equipment. These MVE were necessary to ensure the integrity of the recording electrodes and equipment for the duration of the day.

3.3 Data Manipulation and Analysis

All EMG data recorded on the Biometrics flashcard was downloaded to a computer and imported into the Biometrics program (Gwent, UK). The resulting files were exported into Spike 2 version 5.04 (CED, Cambridge, UK) as text files for custom analysis. Manipulation of the data prior to burst and gap analysis included rectifying the data, smoothing at a time constant of 0.01 seconds and down sampling at a factor of 100 (Spike 2, Cambridge, UK) (Figure 3). Each file was visually analyzed for data artefact, and removed by deletion of the area through custom script (Spike 2, Cambridge, UK). The four channels of data were mapped on the same time constant, thus removal of data from one channel at a particular time stamp removed the same amount of data on the three other channels simultaneously.

Subsequently custom script analysis was employed to calculate the burst and gap composition for each muscle. All channels were normalized to the highest maximal EMG value (%MVE) of each muscle. A burst was defined as having a duration of >0.1 seconds and a threshold amplitude >2% MVE. A gap was also defined as a duration >0.1 seconds, with a threshold amplitude <1% MVE. Bursts and gaps were quantified as (Appendix G):mean duration of the burst/gap (seconds per burst/gap), rate of bursts/gaps (average number of bursts/gaps per second for total recording time), the percentage of burst/gaps (percentage of total recording time) and the total duration of burst/gaps (seconds), peak amplitude (%MVE) and mean peak amplitude of total burst/gap activity (%MVE). As well, the mean area of the bursts and gaps and the total burst/gap area (MVE*s) were calculated.

All GPS data collected on the Garmin receiver unit were downloaded onto a computer, imported into the Garmin Training Center software, and saved in formats appropriate for Google Earth™ (Google, Inc., Mountain View, CA) for off-line analysis. The mapping service was used to define mobility outside the principle residence. Each subject's life-space movement (Peel et al., 2005) was subsequently classified based upon separation factors of: (1) subject remaining solely within their principle residence (low mobility); or (2) movement outside principle residence into the external environment (high mobility). Data for high mobility subjects included distance travelled, time travelled and average speed travelled for independent ambulation and vehicular transport within the outdoor environment.

3.4 Statistical Analysis

Analysis was performed using Statistical Package for the Social Sciences (SPSS; ver. 17.0, Chicago, Ill.). To evaluate physical activity, and mobility, between retirement and community-dwellers, independent t-tests were utilized to analyze the Yale Physical Activity Survey and Paffenbarger Physical Activity Questionnaire scores as well as the GPS measures (distance travelled, time travelled and average speed travelled) and pedometer values (total step counts). A paired t-test was utilized to compare the morning and evening EMG values for the maximum MVE from each session to ensure the integrity of the testing apparatus. The dependent variables of the burst and gap characteristics were compared with a 2 x 2 x 4 multivariate analysis of variance (MANOVA) for living environment (retirement, community-dwelling), mobility (high, low) and muscle group (biceps, triceps, vastus lateralis, biceps femoris). The probability level for all statistical measures was set at an alpha significance of $p<0.05$. Independent t-tests were used to dissociate differences when significant interactions were generated. Data were presented as values ± standard deviation of the mean (SD) in the tables and text, whereas the figures were reported as values ± standard error of the mean (SEM).

3.5 Results

Subject Characteristics

Of the 23 recruited subjects, complete data sets of four EMG channels, pedometer and GPS were acquired in nine retirement facility-dwellers (n=9) and nine community-dwellers (n=9). The health characteristics of the community-dwelling subjects did not differ from the retirement-dwelling subjects (Table 1). The community-dwelling subjects reported a higher number of foot/back problems and muscle/joint problems relative to the retirement-dwellers (32%). Both groups had similar physician diagnosed and subject reported cardiovascular disease, and diabetes (Table 1). All subjects were right hand dominant.

Table 1. Health characteristics reported for community and retirement-dwellers

		Community (n=9)	**Retirement (n=9)**
	Age (yrs)	80 ± 4	84 ± 6
	Weight (kg)	64.7 ± 7.8	65.0 ± 10.7
	Height (cm)	159.5 ± 5.2	159.2 ± 6.4
	BMI	25.5 ± 3.5	25.7 ± 4.0
No. of Health Problems	**Medications**	6.7 ± 3.5	4.8 ± 3.1
	Foot/Back Problems	6	3
	Arthritis	5	4
	Muscle/Joint Problems	6	1
	Cardiovascular Problems	12	12
	Diabetes	2	2

Values are mean ± SD. yrs, years; kg, kilograms; cm, centimetres; BMI, body mass index; No, number of occurrences, p > 0.05.

Physical Activity & Mobility

Both groups reported similar physical activity patterns as measured by the Paffenbarger Physical Activity Questionnaire and Yale Physical Activity Survey (Table 2). Classification of IADL based on Lawton and Brody (1969) indicated from the Yale scores that the community-dwellers perform ~65% more minutes per week of IADL than the retirement-dwellers (Table 2).

Table 2. Self-report physical activity for community and retirement-dwellers

		Community (n = 9)	Retirement (n = 9)
Paffenbarger Scores (kcal/wk)		3496. 71 ± 2463. 55	1846.00 ± 1432.64
Yale Scores	**IADL (min/wk)**	1735.0 ± 623. 24*	600.56 ± 376.12
	Recreational (min/wk)	453.33 ± 517.98	230.0 ± 256.76
	Exercise (min/wk)	155.0 ± 240.7	337.78 ± 424.82

Values are mean ± SD. n, total number of occurrences; min/wk, minutes per week; IADL, instrumental activities of daily living; * $p \leq 0.01$.

The number of steps recorded during the 8-hours of recording were similar between community and retirement-dwellers ($p = 0.3$) (Table 3). Global position system data collected enabled determination of life-space movement segregates where 50% of each living environment category was classified as high mobility (travelled outside of principle residence) and 50% as low mobility (remained within principle residence). Subsequent analysis of the high mobility subjects indicated no difference between community-dwelling and retirement-dwelling for total time travelled, distance travelled while walking and/or driving and for average speeds during ambulatory and vehicular movement (Table 3).

Table 3. Mobility measures using pedometer and GPS of the community and retirement-dwellers

		Community (n=9)		Retirement (n=9)	
		High Mobility (n=4)	**Low Mobility (n=5)**	**High Mobility (n=5)**	**Low Mobility (n=4)**
Pedometer (steps/day)		2498.1 ± 3030.1		898.1 ± 633.8	
		2818.4 ± 3369.6	614.3 ± 487.8	1210.0 ± 476.1	586.3 ± 671.7
GPS Measures	**Total Time (min)**	45.0 ± 59.2		58.8 ± 66.4	
	Walking Distance (km)	1.7 ± 1.9		1.90 ± 0	
	Average Walking Speed (km/hr)	4.0 ± 1.0		3.0 ± 0	
	Driving Distance (km)	11.3 ± 13.5		14.2 ± 12.6	
	Average Driving Speed (km/hr)	63.8 ± 20.6		60.0 ± 8.7	

Values are mean ± SD. n, total number of subjects; min, minutes; km, kilometres; km/hr, kilometres per hour; GPS, global positioning system, $p > 0.05$.

Daily EMG Recordings

The maximal EMG from the morning and evening sessions did not differ ($p > 0.001$). As a result, the highest MVE recorded, irrespective of the session, was used to normalise the daily 8-hour EMG for subsequent burst and gap analysis. Total time recorded between the community-dwelling subjects (7.7 ± 0.9 hrs) and the retirement-dwelling subjects (7.8 ± 0.6 hrs) was also non-significant ($p = 0.7$).

The 2 x 2 x 4 MANOVA evaluating living environment (community-dwelling and retirement-dwelling), mobility (high and low) and muscle (biceps brachii, triceps brachii, vastus lateralis and biceps femoris) for both EMG bursts and gaps was not significant. The interaction between living environment and mobility, and the interaction between mobility and muscle were also non-significant for both EMG characteristics. The interaction between living environment and muscle for

EMG burst characteristics was significant (p = 0.01). Gap analysis of EMG measures also indicated a significant 2-way interaction between living environment and muscle (p < 0.001).

Interactions

<u>Bursts</u>

A significant burst interaction was found between living environment and muscle (p = 0.01) (Figure 4). The dependent variable of peak amplitude contributed to this interaction where the triceps brachii and biceps femoris of community-dwelling subjects was compared with subjects residing in retirement facilities was greater (p < 0.05). In the community-dwelling group burst amplitude in the biceps femoris was higher than the vastus lateralis, triceps brachii and biceps brachii (p = 0.01). Whereas, in the retirement group the biceps brachii had a greater burst amplitude than the vastus lateralis and biceps femoris (p = 0.03) (Figure 4).

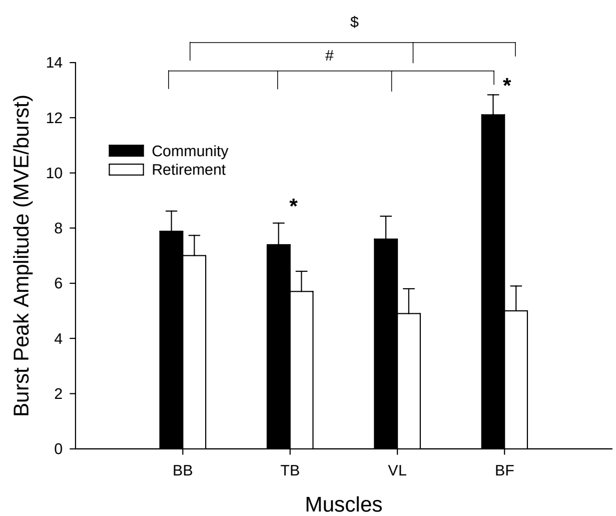

Figure 4. Burst peak amplitude for the community-dwellers (filled bars) and retirement-dwellers (open bars) for the biceps brachii, triceps brachii, vastus lateralis and biceps femoris. * significant difference (p<0.05) between community and retirement. #, significantly higher biceps femoris within community group compared with biceps brachii, triceps brachii and vastus lateralis. $ significantly higher biceps brachii within retirement group compared with vastus lateralis and biceps femoris. MVE, maximal voluntary exertion; BB, biceps brachii; TB, triceps brachii; VL, vastus lateralis; BF, biceps femoris. Data are mean $\pm$ standard error of mean.

Burst duration also caused the interaction between environment and the muscle. The biceps brachii of community-dwelling subjects was greater when compared with subjects residing in retirement homes (p = 0.03). In the community-dwelling group burst duration in the biceps femoris was higher than the triceps brachii (p = 0.03). In the retirement group burst duration in the biceps femoris was higher than the biceps brachii (p < 0.001) (Figure 5).

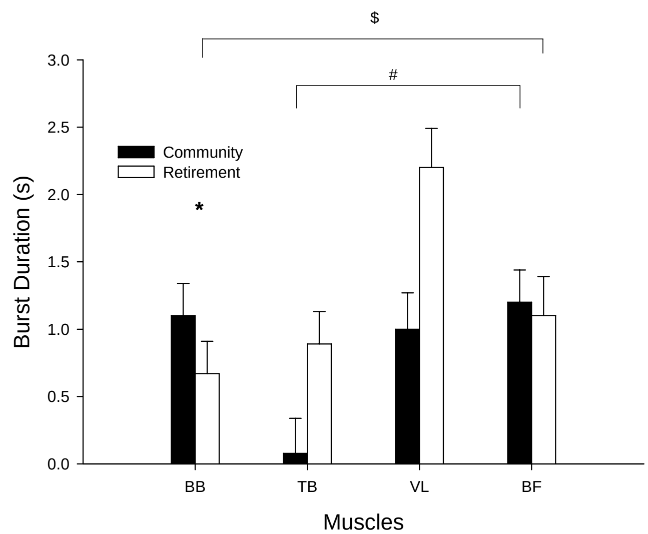

Figure 5. Burst duration for the community-dwellers (filled bars) and retirement-dwellers (open bars) for the biceps brachii, triceps brachii, vastus lateralis and biceps femoris. * significant difference (p>0.05) between community and retirement. #, significantly higher biceps femoris within community group compared with triceps brachii. $ significantly higher biceps femoris within retirement group compared with biceps brachii. s, seconds; BB, biceps brachii; TB, triceps brachii; VL, vastus lateralis; BF, biceps femoris. Data are mean ± standard error of mean.

Gaps

There was an interaction between living environment and muscle (p < 0.001) for EMG gap measures that occurred as a consequence of gap percent (p = 0.016) (Figure 6). Community-dwelling subjects had a higher gap percentage for the vastus lateralis than retirement-dwelling subjects (p = 0.01). The biceps brachii for the community-dwelling was also significantly lower than the vastus lateralis, while the triceps brachii was significantly greater than the vastus lateralis and biceps femoris (p < 0.05).

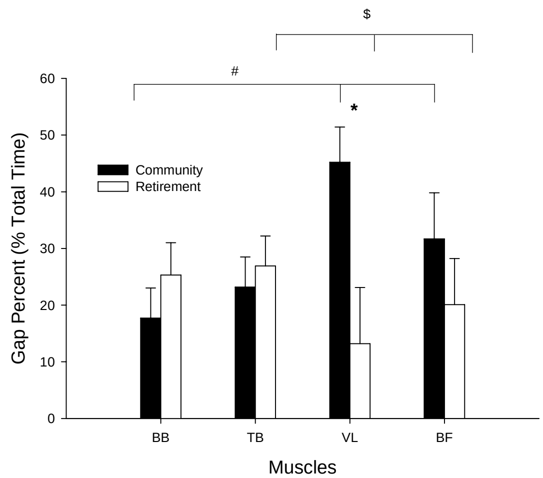

Figure 6. Gap percentage for the community-dwellers (filled bars) and the retirement-dwellers for the biceps brachii, triceps brachii, vastus lateralis and biceps femoris. * significant difference (p>0.05) between community and retirement. #, higher vastus lateralis activity compared with biceps brachii for the community-dwellers. $ significantly higher triceps brachii activity compared with vastus lateralis and biceps femoris in retirement-dwellers. %, percentage; BB, biceps brachii; TB, triceps brachii; VL, vastus lateralis; BF, biceps femoris. Data are mean ± standard error of mean.

Main Effects

Bursts

Main effects of environment (p < 0.001) and muscle (p = 0.005) were observed. Community-dwellers had ~ 20% lower burst number and burst rate compared to retirement-dwellers (p < 0.05) (Figure 7A, 7B). Community-dwellers additionally had ~30% less total burst duration than retirement-dwellers (p = 0.38) (Figure 7C). Conversely, retirement-dwellers had ~ 35% lower peak amplitude than community-dwelling subjects (p < 0.001), (Figure 7D). Significant differences were also found between muscles for several burst characteristics. Both the biceps brachii (11833 ± 2474) and triceps brachii (12908 ± 2926) had a greater number of bursts than the biceps femoris (8479 ± 2705), (p < 0.05) (Figure 8A). For burst duration, the vastus lateralis had ~ 47% longer duration than triceps brachii, and biceps brachii (p < 0.05) (Figure 8B).The biceps femoris had ~25% greater burst peak amplitude than the triceps brachii and the vastus lateralis ($p < 0.05$) (Figure 8C). The biceps femoris had ~45% greater burst activity than the biceps brachii, triceps brachii and vastus lateralis, ($p < 0.05$) (Figure 8D). Burst rate in the biceps femoris was ~33% smaller than the biceps brachii and the triceps brachii ($p < 0.05$) (Figure 8E).

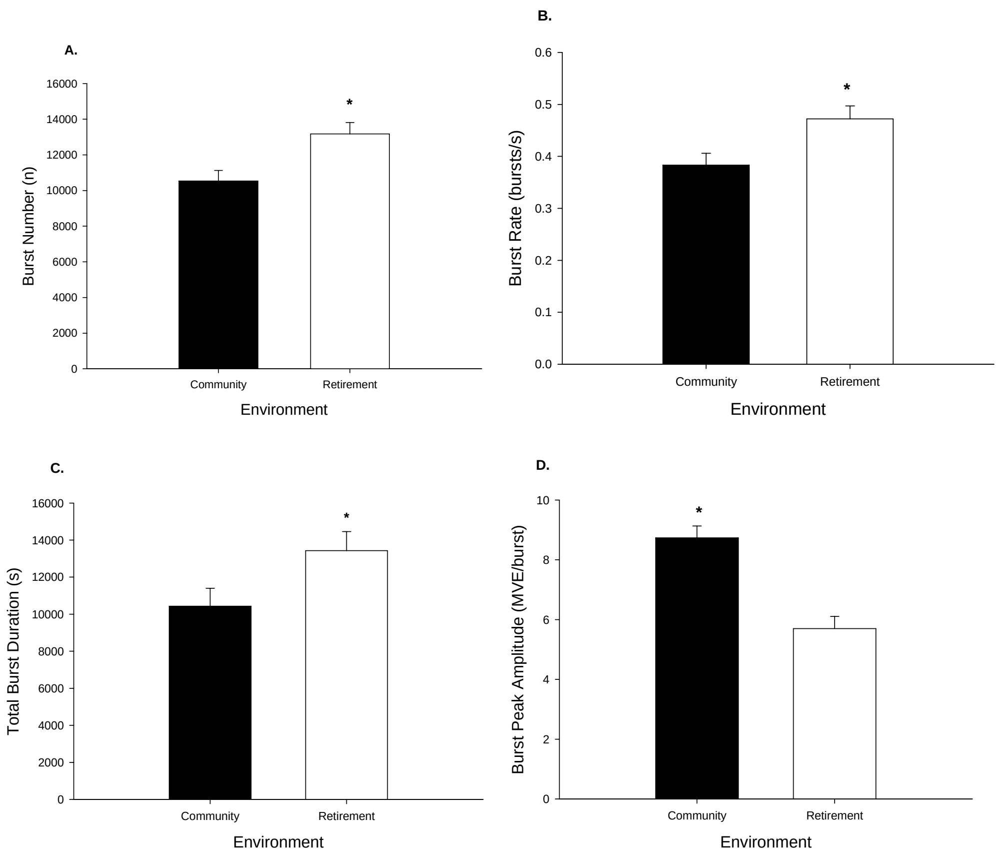

Figure 7. Burst activity for the community-dwellers and retirement-dwellers burst number (A), burst rate (B) total burst duration (C), burst peak amplitude (D). n, number of bursts; s, seconds; MVE, maximal voluntary exertion; BB, biceps brachii; TB, triceps brachii; VL, vastus lateralis; BF, biceps femoris. Data are mean ± standard error of mean. * significant difference ($p < 0.05$) between community and retirement-dwellers.

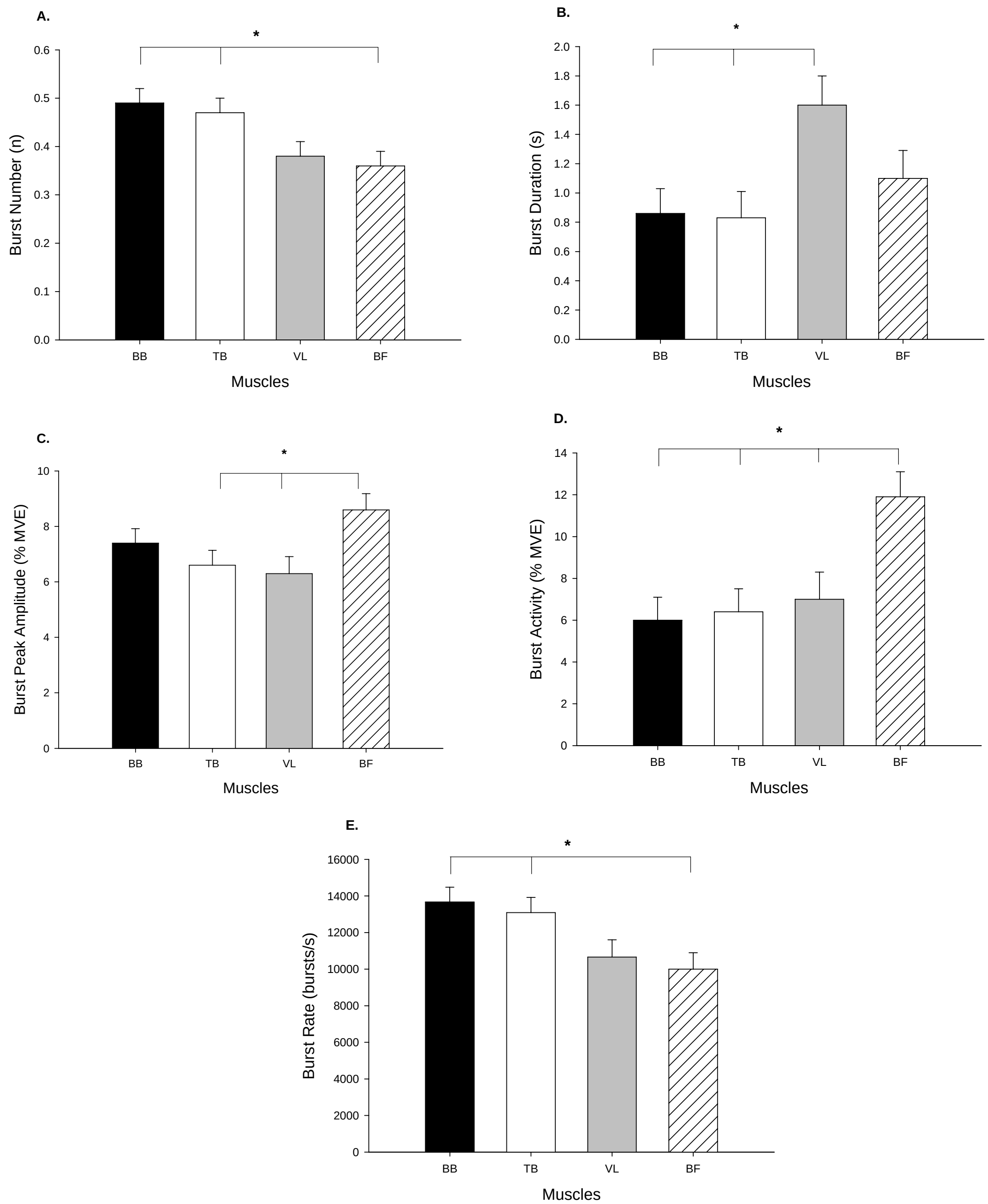

Figure 8. Burst activity for the biceps brachii, triceps brachii, vastus lateralis and biceps femoris. Values for (A) burst number, (B) burst duration (C) burst peak amplitude (D) burst activity (E) burst rate. (A). Burst number was lower in the biceps femoris than in the biceps brachii (p = 0.02) and the triceps brachii (p = 0.03). (B). Vastus lateralis had greater burst duration than the biceps brachii (p = 0.03) and the triceps brachii (p = 0.03). (C). Burst peak amplitude was greater in the biceps femoris than the triceps brachii (p = 0.04) and the vastus lateralis (p = 0.05). (D). Biceps femoris demonstrated greater burst activity than the biceps brachii (p = 0.004), triceps brachii (p = 0.009) and vastus lateralis (p = 0.04). (E). Biceps femoris had lower burst rate than biceps brachii (p = 0.024) and triceps brachii (p = 0.04). n, number of occurrences; s, seconds; %, percentage; MVE, maximal voluntary exertion; BB, biceps brachii; TB, triceps brachii; VL, vastus lateralis; BF, biceps femoris. Data are mean $\pm$ standard error of mean. * $p < 0.05$.

Gaps

Main effects for gaps included living environment and muscle groups (p < 0.05). A comparison of the main effect of living environment indicated that the community-dwelling had ~ 46% significantly greater gap area and ~40% greater total gap area than the retirement-dwellers (p < 0.05) (Figure 9A, 9C). A comparison of the main effect of muscle indicated the triceps brachii had a greater number of gaps (12224.71 $\pm$ 5149.57) as compared to the biceps brachii (7194.54 $\pm$ 2202.22) (p = 0.012) (Figure 9B). Gap rate was ~40% greater in the triceps brachii than the biceps brachii (p = 0.006) (Figure 9D).

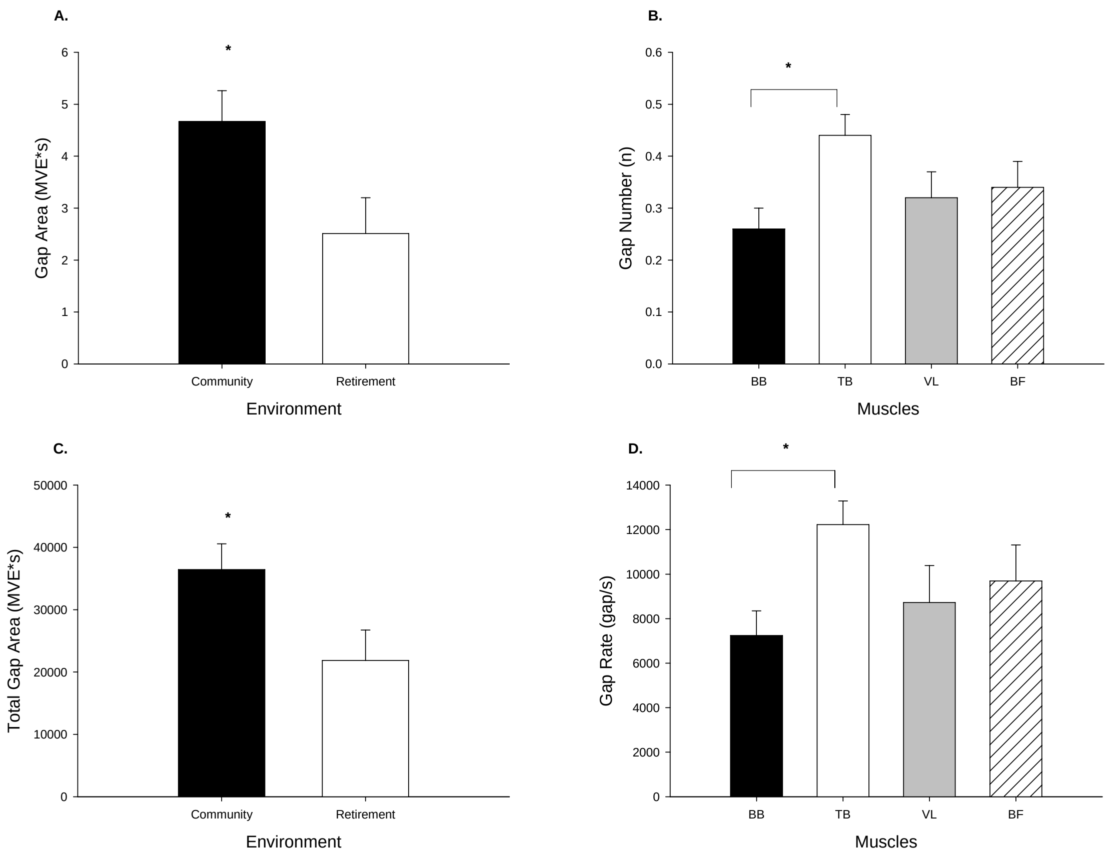

Figure 9. Gap activity for community-dwelling and retirement-dwelling (A, C) as well for the biceps brachii, triceps brachii, vastus lateralis and biceps femoris (B, D). Values for gap area (A), gap number (B), total gap area (C) and gap rate (D). (A). Community-dwellers had greater gap area compared to retirement-dwellers (p = 0.02). (B). Triceps brachii demonstrated greater gap number relative to biceps brachii (p = 0.016). (C). Total gap area was greater in the community-dwelling groups as compared to the retirement-dwelling group (p = 0.03). (D). The triceps brachii had greater gap rate as compared to the biceps brachii (p = 0.008). %, percentage; MVE, maximal voluntary exertion; s, seconds; n, number of occurrences; BB, biceps brachii; TB, triceps brachii; VL, vastus lateralis; BF, biceps femoris. Data are mean $\pm$ standard error of mean. * p < 0.05.

3.6 Discussion

Chronic low threshold EMG activity (bursts and gaps) in older adult women is known to be greater than that of young women (Harwood et al., 2008) but the underlying cause remains to be determined. The purpose of this study was to measure low-threshold EMG for an 8-hour day in older women living in two unique environments (community-dwelling compared to retirement-dwelling) to determine whether mobility or ADL influence muscle activation. Pedometer and GPS scores were not different between community-dwelling and retirement-dwelling older women. When women were segregated based upon high and low life-space movement (Peel et al., 2005) chronic low threshold EMG was similar between groups. These findings suggest that the decrease in burst activity and increase in gap activity in community-dwelling compared with retirement-dwelling women is not associated with mobility. The Yale Physical Activity Survey for Older Adults indicated that the community-dwellers participated in higher daily activity due to increased performance of IADL relative to the retirement-dwellers. Differences in low-threshold EMG in healthy ambulatory women are due to self-reliant tasks undertaken during a day.

Pedometer and GPS scores were similar between retirement- and community-dwelling older women and when the GPS was utilized to group older women as either exhibiting high or low life-space movement, no differences in ambulation (steps per day) were observed. The life-space categorization based on activities that extend from an identified location, usually where a subject sleeps, and into the community is a flexible categorization for the analysis of life-space movement (Peel et al., 2005). Unfortunately, life-space tools give no indication of the intensity of activity within each zone. Self-report may aid in identification of type and intensity of activity in life-space categorization. The retirement-dwelling women in this study received access to exercise and activity programs that resulted in similar intensity and general activity scores compared to the community-dwelling women. Statistical analysis of the physical activity questionnaire scores indicated a difference between community- and retirement-dwelling women for total number of hours of physical activity per week (community: 41.9 ± 12.1 hrs/wk; retirement: 20.0 ± 14.5 hrs/wk, $p = 0.002$). Conversely, community-dwellers performed a greater number of IADL, as described with self-report questionnaire measures. The Yale physical activity subsection indicated that subjects in retirement facilities do not perform many IADL because these services were provided by staff. In general, community-dwellers demonstrate greater involvement in indoor IADL compared with leisure activity participation (Dallosso et al., 1988). Thus, low daily activity in retirement-dwellers is not due to decreased exercise, rather a decrease in IADL. Prior studies have indicated that energy expenditure is lower in subjects living in care facilities (MacRae, Schnelle, Simmons, & Ouslander, 1996). It may be hypothesised that the type of activity older women are undertaking and not mobility is the primary factor influencing EMG.

Not only were fewer IADL performed in retirement-dwelling older adults but, Shumway-Cook et al. (2002) reported that subjects of a higher mobility status perform more activities per trip into the community (2:1 activities per trip) compared to subjects with lower mobility status (1:1 activities per trip). Thus, although it was anticipated that the community group would have higher mobility, the attenuation may be due in part to the time of year data collection occurred. Several studies have demonstrated that mobility patterns vary between seasons, and data collection in this study was restricted to one season (winter). Merchant, Dehghan and Akhtar-Danesh (2007) reported that between July 1st to September 30th, Canadians are 31-48% more likely to be physically active compared to January 1st through to March 31st. In older adults activity is also influenced by season, with participation in the winter months declining the greatest (Brandon, Gill, Speechley, Gilliland, & Jones, 2009). Reductions due to seasonal variation are also apt to have a smaller effect on retirement-dwelling older adults where IADL are not undertaken, compared with the community-dwellers who undertake activities associated with household maintenance. Greater quantities of physical activity during other seasons might become more prominent in the determination of differences in low-threshold EMG.

Another potential attenuation of mobility differences between groups may be due to the transitional status of subjects residing within the retirement facility. Subjects may reside within a retirement facility not because of their own lifestyle requirements, but because of the requirements of their spouse, and as such these transitional retirement-dwellers maintain the same lifestyle as they participated in prior to moving into a retirement facility. It may be concluded that retirement-dwellers are a heterogeneous populationdue to the variety of reasons for transitioning into a care facility, and because of the number of services provided, and more homogenous to community-dwellers. However, the services offered reduce the amount of activities of daily living performed, specifically IADL, and this is reflected in the EMG.

Differences in low-threshold EMG might be sensitive to the overall type of tasks undertaken for age- and mobility-matched groups. Retirement-dwellers demonstrated greater burst activity and less gap activity over a typical 8-hour day. The retirement-dwelling group had a greater burst number, burst rate and total burst duration, which suggests the muscles were required to be activated, or "on", more often and for longer. In contrast, community-dwellers exhibited greater burst amplitudes coupled with larger gap area and gap percentage, an indication of greater muscle quiescence. Results from earlier work conducted on young adults indicate that in upper arm muscles EMG burst and gap is sensitive to dissociating differences in activity between needle-point and a joy-stick based video game (Bruce, Slipacoff, Brown, Kenno, & Jakobi, 2007). Therefore, the differences in EMG burst and gap activity reported in this investigation between community- and retirement-dwellers may indicate task differences between the two groups, regardless of mobility.

Findings of greater low-threshold EMG activity in retirement-dwellers from this investigation were opposite to the initial hypotheses. The initial burst and gap hypotheses were based upon expected differences in mobility and physical activity patterns between living environments. As no difference between community- and retirement-dwellers for any measures of mobility or physical activity were demonstrated, the resulting EMG findings are indicative of the IADL differences between the two groups of women.

EMG Activity between Muscles

Differences were also indicated between upper (biceps brachii, triceps brachii) and lower extremities (vastus lateralis, biceps femoris). The upper extremities had greater burst numbers, rate and gap area, whereas the lower extremities had greater burst duration, amplitude and activity. The activation of the lower extremity muscles for long time periods and at higher threshold levels suggests that these muscles when "turned on" remained activated longer and more often than the upper extremity muscles. A possible reason for this may be due to a "shuffling" or altered gait (Kochersberger, McConnell, Kuchibhatla, & Pieper, 1996; Rikli, 2000). Whereby, subjects do not fully utilise the swing phase of walking, rather maintain greater contact time with the walking surface. Thereby, minimizing the distance the foot is raised from the ground surface (Au, Dilworth, & Herr, 2006). Suspected shuffling gait of some subjects is supported by the similarity of mean pedometer values collected, to subjects with functional limitations or chronic illnesses (Petrella & Cress, 2004; Tudor-Locke & Myers, 2001).

Additionally, greater burst and gap numbers and rates recorded in the upper extremity might suggest that these muscles are activated and inhibited with greater frequency than lower extremity muscles throughout a typical day. As has been previously reported, decreases in strength measures are typically greater for the lower extremities than the upper extremities (Frontera, Huges, Lutz, & Evans, 1991; Grimby, Danneskiold-Samsoe, Hvid, & Saltin, 1982) and may be a contributing factor to changes in low-threshold EMG due to task performance being altered (Guralnik et al., 1995; Onder et al., 2002). Martin, Syddall, Dennison, Cooper and Aihie-Sayer (2008) reported that task performance (IADL such as cooking or cleaning the household) was positively related to stronger muscle measures as well as higher levels of physical activity. Therefore, it may be suggested that the upper extremity muscle groups exhibited differences in muscle EMG characteristics from the lower extremities based on greater usage of arm muscles while performing ADL.

3.7 Conclusions

Low-threshold EMG activity patterns differ between community- and retirement-dwelling subjects that were similar for health and mobility. Community-dwellers demonstrated greater gap activity and lower burst activity relative to retirement-dwellers. Further, the upper extremity muscles of biceps brachii and triceps brachii exhibited greater frequency of muscle activity, whereas the lower extremity muscles had greater duration of muscle activity. The results of this investigation indicate that rather than mobility being a primary determinant in differences in low-threshold EMG, that performance of IADL contribute to alterations in burst and gap patterns.

3.8 References

Au, S. K., Dilworth, P., & Herr, H. (2006). An ankle-foot emulation system for the study of human walking biomechanics. *Proceedings of the IEEE International Conference on Robotics and Automation, 34,* 2939-2945.

Baltes, M. M. (1995). Dependency in old age: Gains and losses. *Current Directions in Psychological Science, 4*, 14-19.

Bassett, D. R., Cureton, A. L., & Ainsworth, B. E. (2000). Measurement of daily walking distance-questionnaire versus pedometer. *Medicine & Science in Sports & Exercise, 32*, 1018-1023.

Brandon, A., Gill, D. P., Speechley, M., Gilliland, J., & Jones, G. R. (2009). Physical activity levels of older community-dwelling adults are influenced by summer weather variables. *Applied Physiology, Nutrition, and Metabolism, 34,* 182-190.

Bruce, S. H., Slipacoff, T., Brown, R. E., Kenno, K. A., & Jakobi, J. M. (2007). Influence of task and fatigue on burst activity in young women. *Applied Physiology, Nutrition and Metabolism, 32,* S16.

Buchman, A. S., Boyle, P. A., Wilson, R. S., Bienias, J. L., & Bennett, D. A. (2007). Physical activity and motor decline in older persons. *Muscle & Nerve, 35,* 354-362.

Crimmins, E. M., Saito, Y., & Ingegneri, D. (1989). Changes in life expectancy and disability-free life expectancy in the United States. *Population and Development Review, 15,* 235-267.

Crimmins, E. M., Saito, Y., & Ingegneri, D. (1997). Trends in disability-free life expectancy in the United States, 1970-1990. *Population Development and Review, 23,* 555-572.

Dallosso, H. M., Morgan, K., Bassey, E. J., Ebrahim, S. B., Fentem, P. H. & Arie, T. H. (1988). Levels of customary physical activity among the old and very old living at home. *Journal of Epidemiology and Community Health, 42,* 121-127.

Dipietro, L., Caspersen, C. J., Ostfeld, A. M., & Nadel, E. (1993). A survey for assessing physical activity among older adults. *Medicine & Science in Sports & Exercise. 25,* 628-642.

Duncan, M. J., Mummery, W. K., & Dascombe, B. J. (2007). Utility of global positioning system to measure active transport in urban areas. *Medicine & Science in Sports & Exercise, 39*, 1851-1857.

Frontera, W.R., Hughes, V.A., Lutz, K.J., & Evans, W.J. (1991). A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women. *Journal of Applied Physiology, 71*, 644–650.

Grimby, G., Danneskiold-Samsoe, B., Hvid, K., & Saltin, B. (1982). Morphology and enzymatic capacity in arm and leg muscles in 78–81 year old men and women. *Acta Physiologica Scandinavica, 115*, 125–134.

Guralnik, J. M., Ferrucci, L., Simonsick, E. M., Salive, M. E., & Wallace, R. B. (1995). Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *The New England Journal of Medicine, 339*, 556- 561.

Harwood, B., Edwards, D. L., & Jakobi, J. M. (2008). Age- and sex-related differences in muscle activation for a discrete functional task. *European Journal of Applied Physiology, 103,* 677-686.

Jakobi, J. M., Edwards, D. L., & Connelly, D. M. (2008). Utility of portable electromyography for quantifying muscle activity during daily use. *Gerontology, 54,* 324-331.

Johnson, C. S., Meyers, A. M., Jones, G. R., Fitzgerald, C., Lazowski, D. A., Stolee, P., et al. (2005). Evaluation of the restorative care education and training program for nursing homes. *Canadian Journal on Aging*, *24*, 115-26.

Katz, S., Down, T. D., Cash, H. R., & Grotz, R. (1970). Progress in the Development of the Index of ADL. *The Gerontologist, 10,* 20-30.

Kochersberger, G., McConnell, E., Kuchibhatla, M. N., & Pieper, C. (1996). The reliability, validity and stability of a measure of physical activity in the elderly. *Archives of Physical Medicine and Rehabilitation, 77*, 793-795.

Kruskall, L. J., Campbell, W. W., Evans, W. J. (2004). The Yale Physical Activity Survey for Older Adults: Predictions in the Energy Expenditure Due to Physical Activity. *Journal of the American Dietetic Association*, *104*, 1251-1257.

Lawton, M. P., & Brody, E. M. (1969). Assessment of older people: Self-maintaining and instrumental activities of daily living. *The Gerontologist*, *9*, 179-186.

MacRae, P G., Schnelle, J. F., Simmons, S. F. & Ouslander, J. G. (1996). Physical activity levels of ambulatory nursing home residents. *Journal of Aging and Physical Activity, 4*, 264-278.

Martin, H. J., Syddall, H. E., Dennison, E. M., Cooper, C., & Aihie-Sayer, A. (2008). Relationship between customary physical activity, muscle strength, and physical performance in older men and women: findings from the Hertfordshire Cohort Study. *Age & Ageing, 37*, 589- 593.

Merchant, A. T., Dehghan, M., & Akhtar-Danesh, N. (2007). Seasonal variation in leisure-time physical activity among Canadians. *Canadian Journal of Public Health, 98,* 203-208.

Miller, M. E., Rejeski, W. J., Reboussin, B. A., Ten Have, T. R., & Ettinger, W. H. (2000). Physical activity, functional limitations, and disability in older adults. *Journal of the American Geriatrics Society*, 48, 1264–1272.

National Advisory Council on Aging. (2006). *Seniors in Canada 2006 report card* (Catalogue No. HP30-1/2006E). Ottawa, ON: Public Health Agency of Canada.

Onder, G., Penninx, B. W. J. H., Lapuerta, P., Freid, L. P., Ostir, G. V., Guralnik, J. M., et al. (2002). Change in physical performance over time in older women: The women's health and aging study. *The Journals of Gerontology Series A: Biological and Medical Sciences, 57A*, 289-293.

Ontario Ministry of Health and Long Term Care. (2007). *Seniors' care: Residences offering care.* Retrieved November 16, 2008, from http://www.health.gov.on.ca/english/public/program/ltc/12_residential_mn.html.

Paffenbarger, R. S., Jr., Blair, S. N., Min Lee, I., & Hyde, R. T. (1993). Measurement of physical activity to assess health effects in free-living populations. *Medicine & Science in Sports & Exercise*, *25*, 60-70.

Peel, C., Sawyer-Baker, P., Roth, D. L., Brown, C. J., Bodner, E. V., & Allman, R. M. (2005). Assessing mobility in older adults: The UAB study of aging life-space assessment. *Physical Therapy. 85*, 1008-1019.

Petrella, J. K. & Cress, M. E. (2004). Daily ambulation activity and task performance in community-dwelling older adults aged 63-71 years with preclinical disability. *Journals of Gerontology Series A: Biological and Medical Sciences, 59A*, 264-267.

Rikli, R. E. (2000). Reliability, validity, and methodological issues in assessing physical activity in older adults. *Research Quarterly for Exercise and Sport, 71*, 89-96.

Shumway-Cook, A., Patla, A.E., Stewart, A., Ferrucci, L., Ciol, M. A., & Guralnik, J. M. (2002). Environmental demands associated with community mobility in older adults with and without mobility disability. *Physical Therapy, 82*, 670-681.

Statistics Canada. (2007). *Portrait of the Canadian population in 2006, by age, and sex, 2006 census* (Statistics Canada Catalogue No. 97-551-XIE). Ottawa, ON: Ministry of Industry.

Trottier, H., Martel, L., Houle, C., Berthelot, J. M., & Legare, J. (2000). Living at home or in an institution: What makes the difference for seniors? *Health Reports* (Statistics Canada, Catalogue No. 82-003). *11,* 49-61.

Tudor-Locke, C. E., & Myers, A. M. (2001). Methodological considerations for researchers and practitioners using pedometers to measure physical (ambulatory) activity. *Research Quarterly for Exercise and Sport, 72*, 1-12.

Turcotte, M., & Schellenberg, G. (2007). *A portrait of seniors in Canada.* (Statistics Canada Catalogue No. 89-519-XIE). Ottawa, ON: Ministry of Industry.

Wolf, D. A. (1995). Changes in living arrangements of older women: An international study. *The Gerontologist, 36,* 724-731.

Wu, S. C., Leu, S., & Li, C. (1999). Incidence of and predictors for chronic disability in activities of daily living among older people in Taiwan. *Journal of the American Geriatrics Society*, *47,* 1082–1086.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

4.0 Conclusion

Findings from this investigation indicate that community-dwelling older women have similar mobility as retirement-dwelling older women. However, EMG burst and gap activity patterns were different between older women based upon living environment. Retirement-dwellers exhibited greater burst activity and less gap activity compared with older women residing in the community. Greater participation in IADL in community dwelling adults likely influences the low threshold EMG patterns reported in age and mobility matched groups.

4.1 Summary of Specific Objectives

1. To record muscle activity with portable EMG in the biceps brachii, triceps brachii, vastus lateralis, and biceps femoris for a period of 8-hours in older women with different levels of mobility.

   Achieved: EMG burst and gap characteristics were recorded with a portable device during 8-hours of typical daily activity.

2. To measure mobility using pedometer and GPS in independent community-dwelling and retirement-dwelling older women.

   Achieved: Total number of steps, distances and speeds travelled were collected from both community- and retirement-dwellers.

3. To segregate the women by mobility, based upon living environment and compare muscle EMG burst and gap activity between the two groups.

   Not Achieved: GPS and pedometer date were recorded in both retirement and community dwelling older adults. However, there was no strong segregate of high and low mobility based upon absolute scores. Subsequent life-space categorization was undertaken based upon distance travelled from principle residence (Peel et al., 2005). Muscle activity was compared between groups and no differences in EMG were observed. Although mobility did not differ based upon living environment, low threshold EMG was higher in retirement-dwellers compared to community-dwellers.

4. To evaluate levels of physical activity and ADL between the two groups.

Achieved: Physical activity was similar between groups, but IADL was greater in the community-dwellers compared to retirement-dwellers.

4.2 Summary of Research (H_1) and Null (H_0) Hypotheses

H_1: Subjects living in a retirement facility will show an increase in gap activity and a decrease in burst activity relative to community dwelling subjects.

H_0: Rejected: Community-dwellers demonstrated greater gap activity and less burst activity relative to retirement-dwellers.

H_1: Mobility scores of GPS and pedometer in community-dwellers will be higher compared with retirement-dwellers.

H_0: Rejected: GPS and pedometer measures indicated no difference in mobility between community and retirement-dwelling subjects.

H_1: Based upon availability of services women residing in retirement facilities will be less physically active than those remaining in the community.

H_0: Accepted: Based on the services provided, IADL were performed less by retirement-dwellers as compared to community-dwellers.

H_1: ADL will be greater in the community-dwelling compared with retirement-dwelling older women.

H_0: Rejected: ADL were similar between groups, although IADL were greater in community-dwellers.

4.3 Limitations and Recommendations

One of the greatest impediments to this investigation are the limitations inherent in the mobility tools. Pedometers have been reported to underestimate step counts at slower speeds and altered gait patterns (Le Masurier & Tudor-Locke, 2003). It is suggested that for investigations of older adults, an accelerometer would provide a more accurate indication of daily mobility. In addition, accelerometer data can report energy expenditures in conjunction with step counts, identifying ranges of intensity in physical activity performance. Another limitation with the mobility tools is that GPS receiver technology is currently not sufficient to maintain satellite connection for significant durations indoors (Duncan, Badland, & Mummery, in press). Therefore, in evaluating a population who does not frequently leave their primary residence, GPS receivers can only indicate limited life-space movement. In contrast, measures of distance, speed, and geospatial mobility can be reported for subjects who have greater life-space mobility. Both of these mobility tools are also incapable of providing further information regarding specific types of ADL, thus these units provide only a gross measure of mobility.

Impedance in the performance of typical daily activities of the subjects may have been hindered by the portable EMG unit. The size and weight although minimal for younger adults and in prior studies of older adult men and women (Harwood, Edwards, & Jakobi, 2008), was anecdotally reported as a hindrance for the older women. The waist worn unit was reported as cumbersome for walking or toileting, and women of smaller stature found the unit size interfered with sitting postures. These reports of awkwardness of the device might have been coupled with the additional units used (GPS, pedometer). Prior studies had not used three measurement tools simultaneously. Smaller recording units are recommended.

4.4 References

Duncan, M. J., Badland, H. M., & Mummery, W. K. (in press). Applying GPS to enhance understanding of transport-related physical activity. *Journal of Science and Medicine in Sport*.

Harwood, B., Edwards, D. L., & Jakobi, J. M. (2008). Age- and sex-related differences in muscle activation for a discrete functional task. *European Journal of Applied Physiology, 103,* 677-686.

Le Masurier, G. C., & Tudor-Locke, C. (2003). Comparison of pedometer and accelerometer accuracy under controlled conditions. *Medicine & Science in Sports & Exercise, 35*, 867-871.

APPENDICES

APPENDIX A

University of Windsor Research Ethics Board Approval

Office of the Research Ethics Board

University of Windsor
thinking forward

Today's Date:	March 13, 2008
Principal Investigator:	Ms. Sara Bruce
Department/School:	Kinesiology
REB Number:	07-023
Research Project Title:	Comparison of muscle activity between older adults living in the community with those in long-term care facilities
Clearance Date:	February 12, 2007
Project End Date:	January 31, 2009
Progress Report Due:	December 31, 2007; December 31, 2008
Final Report Due:	January 31, 2009

This is to inform you that the University of Windsor Research Ethics Board (REB), which is organized and operated according to the *Tri-Council Policy Statement* and the University of Windsor *Guidelines for Research Involving Human Subjects*, has granted approval to your research project on the date noted above. This approval is valid only until the Project End Date.

A Progress Report or Final Report is due by the date noted above. The REB may ask for monitoring information at some time during the project's approval period.

During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the REB. Minor change(s) in ongoing studies will be considered when submitted on the Request to Revise form.

Investigators must also report promptly to the REB:
a) changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) all adverse and unexpected experiences or events that are both serious and unexpected;
c) new information that may adversely affect the safety of the subjects or the conduct of the study.

Forms for submissions, notifications, or changes are available on the REB website: www.uwindsor.ca/reb. If your data is going to be used for another project, it is necessary to submit another application to the REB.

We wish you every success in your research.

Maureen Muldoon, Ph.D.
Chair, Research Ethics Board

cc: Dr. Jennifer Jakobi, Kinesiology
Mark Curran, Research Ethics Coordinator

This is an official document. Please retain the original in your files.

401 Sunset Avenue, Windsor, Ontario, Canada N9B 3P4 . tel: 519.253.3000 ext. 3948 . web: www.uwindsor.ca/reb

APPENDIX B

Participant Consent Form

Consent to Participate in Research

Comparison of Muscle Activity between Older Adults Living in the Community with those in Retirement Facilities

You are asked to participate in a research study conducted by Sara Bruce, a graduate student and Dr Jennifer Jakobi, from the Department of Kinesiology at the University of Windsor. This study will contribute to my thesis research for my Master of Human Kinetics Degree. (NSERC Discovery Grant).

PURPOSE OF THE STUDY

The purpose of this project is to assess muscle activity with electromyography (EMG) (how often your muscles are active) in older adults. A Global Positioning System (GPS) and a pedometer will also be used to collect information about how far and how much an individual is walking as well.

PROCEDURES

To participate in this study you must be 75 years or older woman that is healthy, cognitively sound and independently mobile without the use of a gait aid (for example: a cane or a walker). All subjects will be asked to meet with the investigator at a designated room within the retirement facility. The time required to participate will include 1 hour to set up the subject with the testing equipment and answer some questionnaires, 8 hours spent by the subject doing normal daily routine, and 20 minutes at the end of the day removing the equipment. This testing is to take place over two days one week apart if the subject currently resides in a long term care facility.

If you volunteer to participate in this study, we would ask you to do the following things:

1. Allow surface electrodes (band-aid like box) to be placed on the skin over your arm and leg muscles.
2. Wear these electrodes and the device for the day to collect the amount of activity of each muscle.
3. Answer some questionnaires that help us understand your daily activities such as how often you climb the stairs or cut the lawn (exercise, self-care, mobility). This will take approximately 30 minutes to complete.
4. Where a watch like device (a Global Positioning System) on your wrist and your waist belt (a pedometer) to help us record where you are active during the day and the number of steps you take.
5. Perform a few maximal effort contractions of your arms and legs, so that we can ensure the device is working properly, and for us to analyse the daily EMG activity.

POTENTIAL RISKS AND DISCOMFORTS
There are minimal risks with participation including the potential for a skin reaction to the adhesive tape or slight muscle discomfort while performing the maximal muscle contraction. We do ask that you refrain from any activities that would get the device wet (showering, bathing, or swimming).

POTENTIAL BENEFITS TO THE SUBJECTS AND/OR TO SOCIETY
This study will help us understand how muscle changes with age, and how muscle activity relates to function and mobility in older adults.

PAYMENT FOR PARTICIPATION
For participating in this study participants will not receive any payment.

CONFIDENTIALITY
Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission.

The subjects used in this study will be retrieved on a voluntary basis only. Each subject will receive a consent form and a letter of information providing the purpose and procedures of the study, and subjects will have the right to withdraw at any time. All data will be coded and locked in the laboratory for use by myself or Dr Jakobi. The obtained research may be used in further studies in order to build upon the findings of the current research, but no subject will be identified in subsequent presentation of the results. Upon completion, the manuscript will be made available on Dr Jakobi's website. The published manuscript will be sent to Windermere on the Mount Long Term Care Facility and a presentation will be made on the results of the study, along with a thank you letter for their involvement. The community dwelling residents will also receive a summary of the results.

PARTICIPATION AND WITHDRAWAL
You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you do not want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE SUBJECTS
Research findings will be made available on Dr Jakobi's website upon publication of the manuscript. As well, the preliminary findings will be discussed with the administrator of the long term card facility, and an in house presentation of the results will be given as well. The community dwelling participants will also receive a summary of the results.

Web address:
http://web4.uwindsor.ca/units/hk/deptKinesiology.nsf.main?ADF9B73E8B85A87485256E4800259D6A?OpenDocument
Data when results are available: ~1 year from onset of the study (fall 2007)

SUBSEQUENT USE OF DATA

Do you give consent for the subsequent use of the data from this study? ☐ Yes ☐ No

RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. If you have questions regarding your rights as a research subject, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; telephone 519.253.3000 ext 3916; email ethics@uwindsor.ca.

SIGNATURE OF RESEARCH SUBJECT/LEGAL REPRESENTATIVE

I understand the information provided for the study Comparison of Muscle activity Between Older Adults Living in the Community with those in Long Term Care Facilities as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____

Name of Subject

______________________________ ______________________

Signature of Subject Date

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

______________________________ ______________________

Signature of Investigator Date

APPENDIX C

Paffenbarger Physical Activity Questionnaire

Paffenbarger Physical Activity Questionnaire

Experiment Date:_______________ Subject Code:_____

Please answer the following questions based on your average daily physical activity habits for the past year.

1. How many stairs did you climb up on an average day during the past year?
   __________ stairs per day (1 flight or floor = 10 stairs)

2. How many city blocks or their equivalent did you walk on an average day during the past year?
   __________ blocks per day (12 blocks = 1 mile)

3. List any sports, leisure, or recreational activities you have participated in on a regular basis during the past year. Enter the average number of times per week you took part in these activities and the average duration of these sessions. Include only time you were physically active (that is, actual playing or activity time).

Sport or Recreation	Times per Week	Time per Episode Hours : Minutes
___________	_______	______ ________
___________	_______	______ ________
___________	_______	______ ________
___________	_______	______ ________
___________	_______	______ ________
___________	_______	______ ________

Paffenbarger Physical Activity Questionnaire
Scoring Worksheet

Experiment Date:_____________ Subject Code:_____

1. Energy expenditure associated with stairclimbing:

_____ stairs climbed/day * 7 days/week = ___ stairs climbed/wk
_____ stairs climbed/week * 8 kcal/20 stairs =
_____ kcal energy expended/week stairclimbing

2. Energy expenditure associated with walking:

_____ blocks walked/day * 7 days/week = ___ blocks walked/week
_____ blocks walked/week * 8 kcal/block =
_____ kcal energy expended/week walking

3. Energy expenditure associated with light sport or recreational activities:

_____ total minutes of light sport/recreational activities/week
* 5 kcal/minute =
______ kcal expended/week in light sport/recreational activities

4. Energy expenditure associated with vigorous sport or recreational activities:

_____ total minutes of vigorous sport/recreational activities/week * 10 kcal/minute =
_____ kcal expended/week vigorous sport/recreational activities

5. Total sport, leisure, and recreational energy expenditure per week:

kcal/wk stairclimbing: __________
kcal/wk walking: __________
kcal/wk light sport/recreational: __________
kcal/wk vigorous sport/recreational: __________
Total kcal/wk expended: __________

APPENDIX D

Yale Physical Activity Survey for Older Adults

THE YALE PHYSICAL ACTIVITY SURVEY FOR OLDER ADULTS

INTERVIEWER: PLEASE MARK TIME: __ __:__ __:__ __
HR MIN SEC

INTERVIEWER: (Please hand the subject the list of activities while reading this statement). Here is a list of common types of physical activities. Please tell me which of them you did during a typical week in the last month. Our interest is learning about the types of physical activities that are a part of your regular work and leisure routines.

For each activity you do, please tell me how much time (hours) you spent doing this activity during a typical week. (Hand subject card #1.)

Work	**Time** (Hrs/Wk)	**Intensity Code*** (kcal/min)
Shopping (e.g., grocery, clothes)	____	3.5
Stair climbing while carrying a load	____	8.5
Laundry (time loading, unloading, hanging, folding only)	____	3.0
Light housework: tidying, dusting, sweeping; collecting trash in home; polishing; indoor gardening; ironing	____	3.0
Heavy housework: vacuuming, mopping; scrubbing floors and walls; moving furniture, boxes, or garbage cans	____	4.5
Food preparation (10+ mins in duration): chopping stirring; moving about to get food items, pans	____	2.5
Food service (10+ mins in duration): setting table; carrying food; serving food	____	2.5
Dish washing (10+ mins in duration): clearing table; washing/drying dishes, putting dishes away	____	2.5
Light home repair: small appliance repair; light home maintenance/repair	____	3.0
Heavy home repair: painting, carpentry, washing/polishing car	____	5.5
Other: ____________________	____	____+

	Time (Hrs/Wk)	Intensity Code* (kcal/min)
Yardwork		
Gardening: planting, weeding, digging, hoeing	____	4.5
Lawn mowing (walking only)	____	4.5
Clearing walks/driveway: sweeping, shoveling, raking	____	5.0
Other: ______________________________	____	____+
Caretaking		
Older or disabled person (lifting, pushing wheelchair)	____	5.5
Childcare (lifting, carrying, pushing stroller)	____	4.0
Exercise		
Brisk walking (10+ mins in duration)	____	6.0
Pool exercises, stretching, yoga	____	3.0
Vigorous calisthenics, aerobics	____	6.0
Cycling, exercycle	____	6.0
Swimming (laps only)	____	6.0
Other: ______________________________	____	____+
Recreational Activities		
Leisurely walking (10+ mins in duration)	____	3.5
Needlework: knitting, sewing, needlepoint, etc.	____	1.5
Dancing (mod/fast): line, ballroom, tap, square, etc.	____	5.5
Bowling, bocci	____	3.0
Golf (walking to each hole only)	____	5.0
Racquet sports: tennis, racquet ball	____	7.0
Billiards	____	2.5
Other: ______________________________	____	____+

INTERVIEWER: (please read to subject). I would now like to ask you about certain types of activities that you have done during the past month. I will ask you about how much vigorous activity, leisurely walking, sitting, standing, and some other things that you usually do.

1. About how many times during the month did you participate in vigorous activities that lasted at least 10 minutes and caused large increases in breathing, heart rate, or leg fatique or caused you to perspire? (Hand subject card #2.)

SCORE: 0 = Not at all (go to Q3)
1 = 1-3 times per month
2 = 1-2 times per week
3 = 3-4 times per week
4 = 5+ times per week
7 = Refused
8 = Don't know **FREQUENCY SCORE** = ______________

2. About how long do you do this vigorous activity(ies) each time? (Hand subject card #3.)

SCORE: 0 = Not applicable
1 = 10-30 minutes
2 = 31-60 minutes
3 = 60+ minutes
7 = Refused
8 = Don't know

DURATION SCORE = ______________

WEIGHT = **5**

VIGOROUS ACTIVITY INDEX SCORE:

FREQ SCORE ___ **x DUR SCORE** ___ **x WEIGHT** ___ = ______________
(Responses of 7 or 8 are scored as missing.)

3. Think about the walks you have taken during the past month. About how many times per month did you walk for at least 10 minutes or more without stopping which was not strenuous enough to cause large increases in breathing, heart rate, or leg fatique or cause you to perspire? (Hand subject card #2.)

SCORE: 0 = Not at all (go to Q5)
1 = 1-3 times per month
2 = 1-2 times per week
3 = 3-4 times per week
4 = 5+ times per week
7 = Refused
8 = Don't know **FREQUENCY SCORE** = ______________

4. When you did this walking, for how many minutes did you do it? (Hand subject card #3.)

SCORE: 0 = Not applicable
1 = 10-30 minutes
2 = 31-60 minutes
3 = 60+ minutes
7 = Refused
8 = Don't know

DURATION SCORE = ______________

WEIGHT = 4

LEISURELY WALKING INDEX SCORE:

FREQ SCORE ____ **x DUR SCORE** ____ **x WEIGHT** ___ = ______________
(Responses of 7 or 8 are scored as missing.)

5. About how many hours a day do you spend moving around on your feet while doing things? Please report only the time that you are <u>actually moving.</u> (Hand subject card #4.)

SCORE: 0 = Not at all
1 = less than 1 hr per day
2 = 1 to less than 3 hrs per day
3 = 3 to less than 5 hrs per day
4 = 5 to less than 7 hrs per day
5 = 7+ hrs per day
7 = Refused
8 = Don't know

MOVING SCORE = ______________

WEIGHT = 3

MOVING INDEX SCORE:
MOVING SCORE _____ **x WEIGHT** ___ = ______________
(Responses of 7 or 8 are scored as missing.)

6. Think about how much time you spend standing or moving around on your feet on an average day during the past month. About how many hours per day do you <u>stand?</u> (Hand subject card #4.)

SCORE: 0 = Not at all
1 = less than 1 hr per day
2 = 1 to less than 3 hrs per day
3 = 3 to less than 5 hrs per day
4 = 5 to less than 7 hrs per day
5 = 7+ hrs per day
7 = Refused
8 = DK

STANDING SCORE = ______________

WEIGHT = 2

STANDING INDEX SCORE:

STANDING SCORE ____ **x WEIGHT** ___ **=** ______________
(Responses of 7 or 8 are scored as missing.)

7. About how many hours did you spend sitting on an average day during the past month) (Hand subject card #5.)

SCORE: 0 = Not at all
1 = less than 3 hours
2 = 3 hours to less than 6 hours
3 = 6 hours to less than 8 hours
4 = 8+ hours
7 = Refused
8 = Don't know **SITTING SCORE = ______________**

WEIGHT = 1

SITTING INDEX SCORE:

SITTING SCORE _____ **x WEIGHT** ___ **=** ______________
(Responses of 7 or 8 are scored as missing.)

8. About how many flights of stairs do you climb up each day? (let 10 steps = 1 flight.)

____

9. Please compare the amount of physical activity that you do during other seasons of the year with the amount of activity you just reported for a typical week in the past month. For example, in the summer, do you do more or less activity than what you reported doing in the past month? (INTERVIEWER: PLEASE CIRCLE THE APPROPRIATE SCORE FOR EACH SEASON.)

	Lot More	Little More	Same	Little Less	Lot Less	Don't know
Spring	1.30	1.15	1.00	0.85	0.70	.
Summer	1.30	1.15	1.00	0.85	0.70	.
Fall	1.30	1.15	1.00	0.85	0.70	.
Winter	1.30	1.15	1.00	0.85	0.70	.

SEASONAL ADJUSTMENT SCORE = SUM OVER ALL SEASONS / 4 ______________

INTERVIEWER PLEASE MARK TIME: __ __:__ __:__ __
HR SEC MIN

CARD #1

WEEKLY PHYSICAL ACTIVITIES

Work

Shopping (e.g., grocery, clothes)	
Stair climbing while carrying a load	
Laundry	
Light Housework:	tidying, dusting, sweeping, collecting garbage in home, polishing, indoor gardening, ironing
Heavy Housework:	vacuuming, mopping, scrubbing floors and walls, moving furniture, moving boxes or garbage cans
Food preparation (10+ min.):	chopping, stirring, moving around to get food items, pots or pans
Food service (10+ min.):	setting table, carrying food, serving food
Dish washing (10+ min.):	clearing table, washing and drying dishes, putting dishes away
Light home repair:	small appliance repair, light household maintenance and repair tasks
Heavy home repair:	painting, washing and polishing car, carpentry
Other:	______________________________

Yardwork

Gardening:	pruning, planting, weeding, hoeing, digging
Lawn mowing (walking only)	
Clearing walks and driveway:	raking, shoveling, sweeping
Other:	______________________________

<u>Caretaking</u>	
Older or disabled person:	lifting, pushing wheelchair
Childcare:	lifting, pushing stroller
<u>Exercise</u>	
<u>Brisk</u> walking for exercise (10+ min.):	causes large increases in heart rate, breathing or leg fatigue
Stretching exercises, yoga, pool exercise	
<u>Vigorous</u> calisthenics, aerobics:	causes large increases in heart rate, breathing or leg fatigue
Cycling, exercycle	
Lap swimming	
Other:	______________________________
<u>Recreational Activities</u>	
<u>Leisurely</u> walking (10+ min.)	
Hiking	
Needlework:	knitting, sewing, crocheting, needlepoint
Dancing (mod/fast):	line dancing, ballroom, square, tap, etc.
Bowling, boccie	
Golf (walking to each hole only)	
Racquet sports:	tennis, racquetball
Billiards	
Other:	______________________________

CARD #2

Not at all
1-3 times per month
1-2 times per week
3-4 times per week
5 or more times per week
Don't know

CARD #3

10-30 minutes
31-60 minutes
60 or more minutes
Don't know

CARD #4

Not at all
less than 1 hour per day
1 to less than 3 hours per day
3 to less than 5 hours per day
5 to less than 7 hours per day
7 or more hours per day
Don't know

CARD #5

Not at all
less than 3 hours per day
3 hours to less than 6 hours per day
6 hours to less than 8 hours per day
8 or more hours per day
Don't know

APPENDIX E

Burst Activity Table of Effects

Table 4. Burst activity table of effects

Effect	Value	F	Degrees of Freedom	Significance	Observed Power
Environment	.540	5.093	39.0	.000	.997
Mobility	.414	3.056	39.0	.007	.937
Muscle	.928	2.039	123.0	.005	.994
Environment * Mobility	.204	1.113	39.0	.376	.465
Environment * Muscle	.869	1.858	123.0	.012	.988
Mobility * Muscle	.699	1.384	123.0	.119	.933
Environment * Mobility * Muscle	.529	.976	123.0	.506	.780

APPENDIX F

Gap Activity Table of Effects

Table 5. Gap activity table of effects

Effect	Value	F	Degrees of Freedom	Significance	Observed Power
Environment	.662	3.478	16.000	.014	.893
Mobility	.657	3.410	16.000	.016	.886
Muscle	1.421	1.799	54.000	.033	.957
Environment * Mobility	.672	3.640	16.000	.012	.908
Environment * Muscle	1.769	2.872	54.000	.000	.999
Mobility * Muscle	1.305	1.539	54.000	.089	.913
Environment * Mobility * Muscle	1.334	1.602	54.000	.070	.926

APPENDIX G

EMG Temporal & Spatial Characteristics

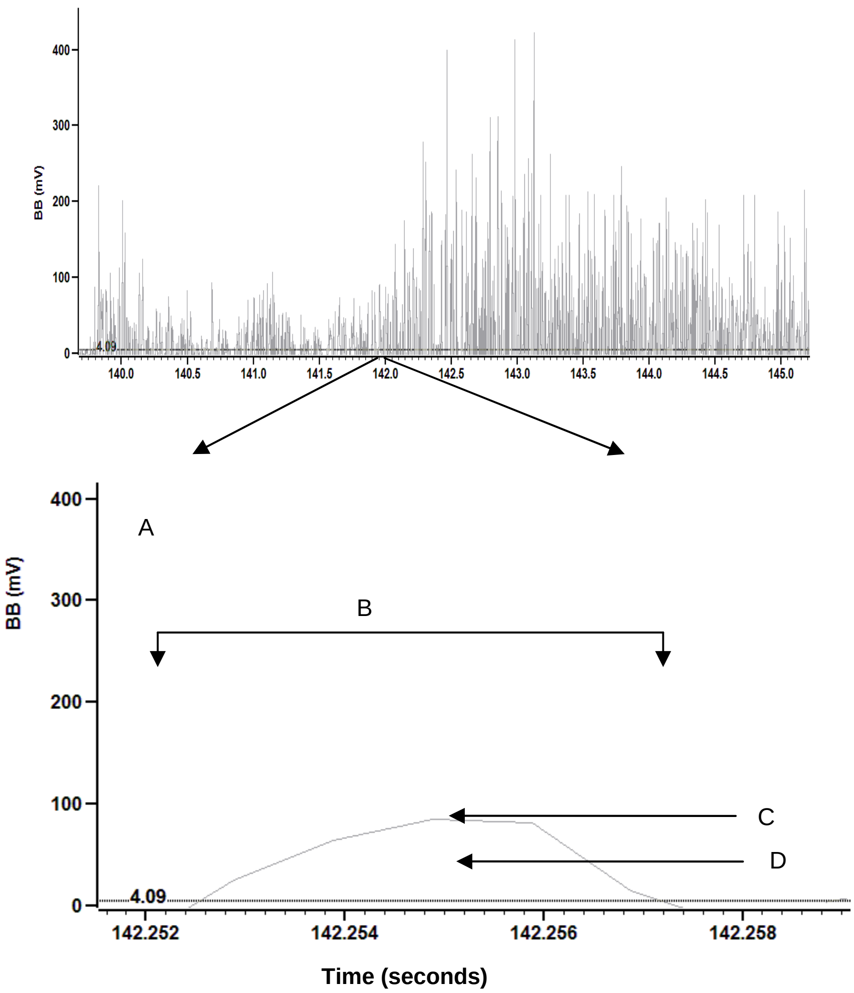

Figure 10. EMG Temporal and Spatial Characteristics. Temporal EMG event characteristics from processed EMG (rectified, smoothed, down-sampled) of the biceps brachii muscle include: A) the number of single EMG events; computed for the duration of each event, B) Event duration (time). Composite temporal characteristics include; Event rate (number of events per unit of time); Event percentage (percentage of the total recording time); Event activity (percentage of the maximal) and Total event duration (total duration of all events). The spatial EMG event characteristics include measures of: C) Event peak amplitude (peak value of EMG); D) Event area (area under the curve). The composite spatial characteristic is the: Total event area (total area of all events). BB, Biceps brachii.

VITA AUCTORIS

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Education

University of Windsor, Windsor, ON
M.H.K. Applied Human Performance **2009**
Thesis: "Influence of mobility and daily activity on low-threshold EMG in older women "

University of Windsor, Windsor, ON
B.H.K. Honours Movement Science **2007**
Independent Study: "The influence of fatigue and discrete task performance on EMG in young women"

Published Abstracts

Bruce, S. H., Slipacoff, T., Brown, R. E., Kenno, K. A., & Jakobi, J. M. (2007). Influence of task and fatigue on burst activity in young women. *Applied Physiology, Nutrition and Metabolism, 32,* S16.

Bruce, S. H., Brown, R. E., Kenno, K. A., & Jakobi, J. M. (2008). Effect of fatigue on EMG burst activity in arm muscles of young women. *Applied Physiology, Nutrition and Metabolism. 35*, S13.

Presentations

Ontario Exercise Physiology Conference, Barrie, ON
Comparison of muscle activity between older adults living in the community with those in assisted living **2008**
Bruce, S. H., Kenno, K. A., Jakobi, J. M.

Canadian Society for Exercise Physiology, Banff, AB
Annual Scientific Meeting
Effect of fatigue on EMG burst activity in arm muscles of young women **2008**
Bruce, S. H., Brown, R. E., Kenno, K. A., Jakobi, J. M.

Canadian Society for Exercise Physiology, London, ON
Annual Scientific Meeting
Influence of task and fatigue on burst activity in young women **2007**
Bruce, S. H., Slipacoff, T., Brown, R. E., Kenno, K. A., Jakobi, J. M.

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University of Windsor, Windsor, ON **2008**
Graduate Assistant – Neuromuscular Physiology 95-460

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Graduate student member