The Effects of a 2-Week Isometric Neck Exercise Training Program on Standing Balance.

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ABSTRACT

The purpose was to assess a neck-specific exercise program on balance performance. Balance was measured using standing tests (Romberg (ROM), Modified Romberg (MROM), and Unipedal Stance) on force plates to assess center of pressure velocity (COPV) with eyes open and closed (EC). Neck endurance was measured using the Cervical Flexion Endurance (CFET) and Cervical Extension Endurance (CEET) tests. Twenty participants were randomly assigned across groups. The exercise intervention involved neck training 3X/week for 2 weeks. Repeated measures ANOVAs showed the intervention group had significant improvements in CFET ($p = 0.005$), thus differing from the control group post-intervention ($p = 0.009$), but no changes in CEET. COPV for ROMEC showed a significant main effect for group ($p = 0.04$), and MROMEC showed a main effect for timepoint ($p = 0.010$). The results show that CFET is a specific tool to increase neck flexion endurance, but further research is required to understand a possible interaction with balance.

LIST OF ABBREVIATIONS & SYMBOLS USED

- BESS = Balance Error Scoring System
- BESTest = Balance Evaluation Systems Test
- CEET = Cervical Extension Endurance Test
- CFET = Cervical Flexion Endurance Test
- COP = Center of pressure
- COPV = Center of Pressure Velocity / Sway velocity
- EMG = Electromyography
- MROM = Modified Romberg Test
- MROMEC = Modified Romberg Eyes Closed
- MROMEO = Modified Romberg Eyes Open
- MVIC = Maximum Voluntary Isometric Contraction
- POMA = Tinetti test, Performance Oriented Mobility Assessment
- ROM = Romberg Test
- ROMEC = Romberg Eyes Closed
- ROMEO = Romberg Eyes Open
- SCM = Sternocleidomastoid
- UL = Unipedal Left Test
- UR = Unipedal Right Test
- ULEC = Unilateral Left Eyes Closed
- ULEO = Unilateral Left Eyes Open
- UREC = Unilateral Right Eyes Closed
- UREO = Unilateral Right Eyes Open

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1. INTRODUCTION

1.1. THE PROBLEM

There is currently no consensus on the best way to train neck musculature to elicit a functional change in performance (Peolsson et al., 2007). This lack of agreement appears to stem from an inability to adequately define terminology used when discussing training for neck musculature. The terms “strength” and “endurance” are used liberally in the literature concerning the cervical spine. The term “strength” on its own is not able to encompass all types and qualities of strength and cannot be used broadly when looking at specific qualities. The same issue is present for the topic of muscular endurance. “Endurance” is used as a blanket term for anything dealing with a task done repeatedly for a long period of time. However, in order to qualify this further, we must distinguish between muscular failure (usually volitional) or the reduction in force output (as a drop in mean electromyographic or EMG frequency) and even between contractile states (isometric versus concentric) (Vøllestad, 1997). These distinctions in terminology need to be considered when evaluating methodological design for specificity towards neck muscle testing and training.

Research has shown high adaptability and trainability in neck muscles as well as establishing its role in human postural stability and balance, but there is still no “gold-standard” for neck training (Hanney & Kolber, 2007; Vuillerme & Pinsault, 2009). Neck muscles can occupy several roles to allow the head and neck to move in conjunction across multiple movement planes, making them difficult to isolate from each other (Conley et al., 1995). The nature of these tightly packed muscle groups means that targeting specific muscles is difficult without standardizing neck position and establishing muscle borders and landmarks, so a directional approach (anterior or posterior for example) to exercise and testing is typically adopted (Javanshir et al., 2010).

Although it has been shown that improvements in neck muscle function leads to better posture, a reduction in neck pain, and a reduction in the incidence of head and neck injuries, many of these improvements are localized to the neck (D. Falla et al., 2006; Lavallee et al., 2013; Vuillerme et al., 2005). Several studies have shown that when the neck is fatigued, whole body balance performance is reduced through interference with neural afferent inflow (Schieppati, Nardone, & Schmid, 2003). The same decrement in performance is found in populations with chronic or acute injuries or impairments to the head or neck (Guskiewicz et al., 2001; N. Yoganandan et al., 1996). It is possible that training the neck for the purpose of balance improvement may help as a rehabilitative or pre-habilitative method of injury prevention and improved overall balance function. This may be possible because of the neck's role in head orientation, and subsequent posture based on head orientation. When neck fatigue increases, this control is interfered with. If neck fatigue can be reduced it may be possible to improve upon peripheral motor control by reducing neural inflow issues, fortifying balance control and improving daily function (Shumway-Cook & Horak, 1986; Winter, 1995).

1.2. PURPOSE

The purpose of this study is to assess neck endurance and standing balance changes in adults before and after a neck specific training program to determine if changes in standing balance occur alongside improvements in neck muscle endurance. Currently, no definitive guidelines exist that use isometric and unloaded neck exercise as a method for improving standing balance. In the proposed study, changes in neck endurance will be compared to changes in center of pressure velocity, which is considered a valid and reliable measure of balance performance (Li et al., 2016; Liang et al., 2014; Lin et al., 2008). These performance changes from baseline would be compared both before and after a training program designed to increase neck endurance. The creation of a viable and effective training program that uses unloaded isometric neck exercise to address whole body balance could potentially provide a simple and inexpensive method to improve prevention and rehabilitation strategies for those suffering from head and neck injuries, balance disorders, age related declines in balance, and neck dysfunction, as well as a method to improve balance for those who cannot utilize more demanding methods of training, such as leg exercises.

1.3. OBJECTIVES

1.3.1. To assess the efficacy of a 2-week isometric neck training program on neck muscle endurance.

1.3.2. To determine the relationship between neck endurance and center of pressure velocity.

1.4. HYPOTHESES

1.4.1. Neck flexion and extension endurance will improve following participation in the 2-week neck endurance program.

1.4.2. Neck endurance improvements will be larger in flexion than in extension.

1.4.3. An improvement in neck endurance (increased time held) will be related to an improvement in center of pressure velocity performance (decrease in sway velocity).

1.5. RESEARCH RELEVANCE

There are several ways in which this research may hold significance and be relevant to current problems:

1.5.1. Head and neck injuries in the athletic population are often a cause for declines in neck and balance function due to traumatic changes in muscle coordination and function (Collins et al., 2014; Hildingsson et al., 1989; Lincoln et al., 2011; Uhlig et al., 1995). This project would provide the first relevant training program to improve neck and balance function simultaneously through exercise. This would pioneer research into training the neck for whole-body stability and balance improvements.

1.5.2. Concussions are a serious concern in sport; this project would provide a viable and proven training program for injury prevention and rehabilitation regarding concussions. This could stimulate further research for protocols to use in sport specific contexts to prepare athletes by mitigating the neural disruptions in sensory information caused after withstanding forces that lead to whiplash or concussions or speed up their recovery following a traumatic event. This is not a claim to alter brain function, but simply as a buffer for body stability following the destabilizing effects of a concussion or whiplash type injury (Collins et al., 2014).

1.5.3. Neck pain is a common chronic problem in sedentary workplaces (Rezasoltani et al., 2012; Schüldt, 1988). This project would assist in the reduction of neck fatigue, potentially reducing the incidence of neck pain in the workplace. This falls in line with a large body of research currently available but is novel in its attempt to influence improvements to balance directly (D. Falla et al., 2006).

1.5.4. This project could provide a program that would be useful for reduction or mitigation of balance changes in patients suffering from acute or chronic conditions that affect balance.

1.5.5. The aging population is at a significant risk of falls, which can lead to serious injuries and an increase in morbidity (Ambrose et al., 2013). If shown to be effective, the use of this type of training could supplement current balance training programs in the aging population to reduce the risk of falls.

1.6. LIMITATIONS

There were some methodological limitations in the study. In that this was a novel study, there was a chance that no significant improvements would occur. Throughout the study, self-reported information was collected from participants. This included activity levels, training history and frequency, day-to-day schedules as well as injury history. We did not perform supervision throughout the training intervention, so assumptions were made as to whether participants were following guidelines properly or had given truthful information to the researchers. This was mitigated by monitoring through training, reporting and a weekly check-in from each participant as well as consistent instruction on how to perform the exercises in the program. A possible limitation was subjective effort from each participant, regardless of the guidelines provided. Many of the tests for neck endurance required maximal isometric holds for time; endurance testing, and training is known to cause significant muscular discomfort. Participants were strongly encouraged and motivated to provide maximal efforts for each test.

2. LITERATURE REVIEW

2.1. THE CERVICAL SPINE

2.1.1. BIOMECHANICS & ANATOMY

To understand why the neck plays a key role in overall posture, the organization of its structures and tissues must be well understood. The human cervical spine is oriented posterior to the center of mass of the head, attaching at the occiput of the skull (Yoganandan et al., 1996). Attached at the occiput is the atlas (C1) and axis (C2) levels of the cervical spine, both of which can move independently through cervical flexion and extension. Lateral bending causes all upper spine segments to shift together, whereas rotation mostly occurs in the upper segments of the cervical spine (Penning, 1978). Below this point the cervical spine is organized lordotically to support the head atop the body, where cervical muscles are arranged to allow for this lordosis to occur and smoothly distribute forces down through the spine (Olson et al., 2006). Cervical muscles (especially superficial ones such as the upper trapezii) act to maintain cervical stability during resting postures (quiet standing and sitting) and complex movements (bending and rotation simultaneously), and are constantly acting to support the head despite its posterior orientation (Olson et al., 2006).

Due to the neck's posterior placement, flexion causes lengthening of the spinal column, while extension compresses it (especially at the occiput) creating a first-class lever effect (Brough, 1994; Penning, 1978; Strimpakos, 2011a) . Cervical range of motion typically falls within 80-90 degrees of flexion, 70 degrees extension, 20-45 degrees of lateral flexion and up to 90 degrees of rotation (Swartz et al., 2005). Passive range of motion at the cervical spine increases the range that can be demonstrated (Strimpakos, 2011a). The first class lever organization of the cervical spine allows cervical muscles to have a greater mechanical advantage against the weight of the head, but this creates an inherent restriction in cervical flexibility as the segments possess limited end-range movement regardless of direction moved before the tissues are unable to extend further, or the skull and superficial tissues restrict further movement (rotation typically maxes out at 80-90 degrees for example) (see Figure 1) (Brough, 1994).

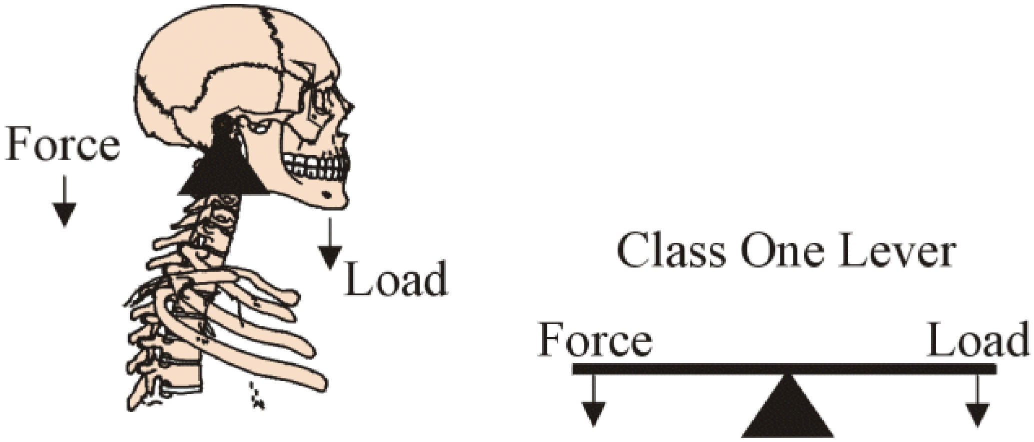

Figure 1: Biomechanical lever system of the cervical spine. (Brough, 1994)

Neck muscles are grossly categorized into two groups: flexors and extensors, which can be further differentiated into superficial and deep muscles (Sniezek & Sofferman, 2012). Neck flexors and extensors have been shown to generate considerable forces and act as dynamic stabilizers of the cervical spine by working in synergy (see Figures 2 and 3 for flexors and extensors, respectively) (Nolan & Sherk, 1988). Superficial extensors such as the levator scapulae, upper trapezius (which are also considered muscles of the shoulder girdle), and splenius capitis act to initiate neck extension as well as rotation and ipsilateral side bending (Schomacher & Falla, 2013). The semispinalis capitis, semispinalis cervicis & multifidus (which cross into the thoracic spine) are the next layer of extensor muscles, providing stability across the entirety of the cervical spine (Schomacher & Falla, 2013). The deepest extensors are the rectus capitis posterior (major & minor) and obliquus capitis superior & inferior which have smaller moment arms as well as multiple attachments and are predominantly composed of slow twitch muscle fibers (~70%) acting on the C1 and C2 levels which allows them to provide stability even while under fatigue (Schomacher & Falla, 2013). Cervical flexors play a predominant role in sustaining postures over long periods of time (G. A. Jull et al., 2008). The longus capitis and longus colli muscles are responsible for the previously mentioned craniocervical flexion to stabilize the spine (G. A. Jull et al., 2008). Other muscles in the flexor group occupy very different roles than the capitis and colli. The sternocleidomastoid (SCM) muscle also assists in cervical extension, lateral bending and rotation, while the anterior scalenes provide flexion stability to the cervical spine (Garces et al., 2003; G. A. Jull et al., 2008).

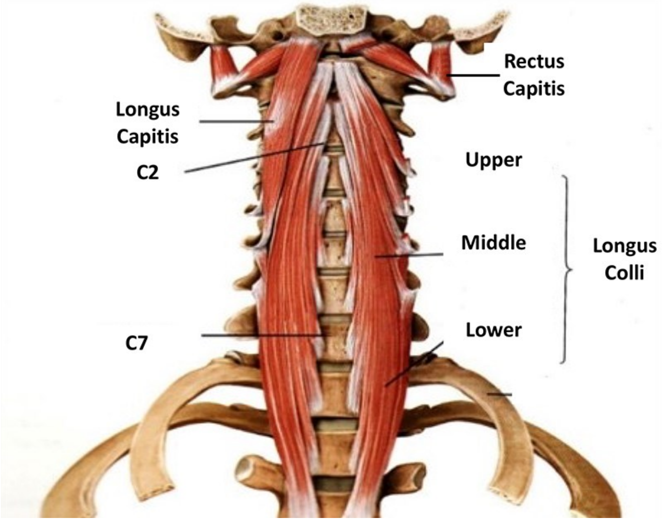

Figure 2: Deep Neck Flexors (The Most Overlooked Cause of Neck Problems | ChiroUp, n.d.)

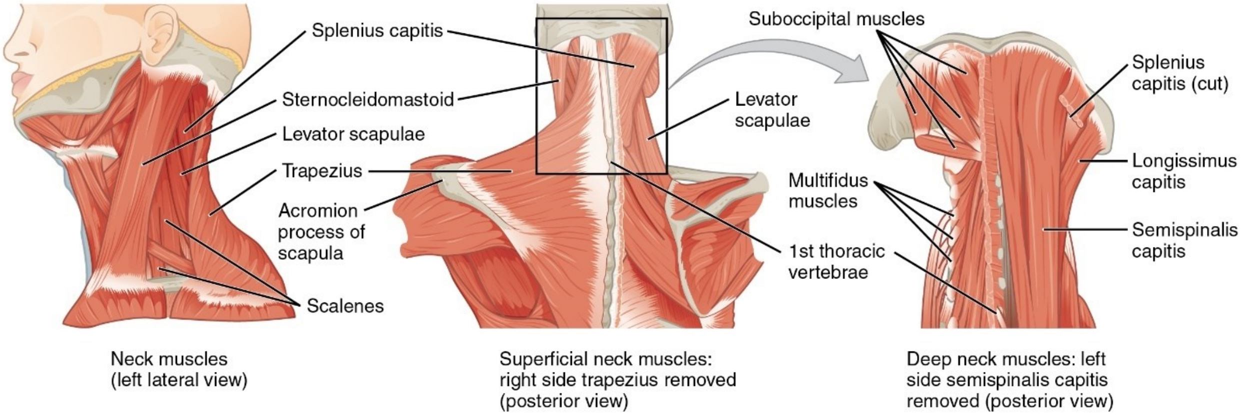

Figure 3: Flexors and Extensors of the Neck (Betts et al., 2013)

The cervical spine is designed efficiently to dissipate force and move in complex multi-planar movements, and its movement efficiency is dependent on the coactivation of muscles on the dorsal and ventral aspects of the neck (S. J. Edmondston et al., 2008). Adequate neck posture is found when the head is held with a horizontal gaze and a slight chin tucked position is adopted; this minimizes loading through the cervical spine by creating a more rigid posture that requires less effort to maintain (Bonney & Corlett, 2002). This posture could be considered equilibrium for the cervical spine through the subtle muscle coactivation that occurs from the "chin-tucked" position (also known as craniocervical flexion) where there is increased deep neck muscle activity (Harris et al., 2005). While in this neutral position, superficial flexors are at an optimal length and serve to initiate gross movements when needed, instead of operating in a flexed and shortened position (Jull & Falla, 2016). Deep neck flexors (such as the longus colli) act as a stabilizing sleeve for the cervical spine against gravity while the chin is tucked, augmenting the lever operation of neck extensors (Harris et al., 2005; Mayoux-Benhamou et al., 1994). Any muscle impairments or inefficient postures (forward leaning or excessive tilting) can lead to postural instability, interfering with natural postural design of the neck (Bonney & Corlett, 2002; Harris et al., 2005).

The human neck is sensitive to deformation when subject to high compression loads and its natural stability is overcome (Yoganandan et al., 1990). Soft tissues in the neck, including muscles and tendons, govern responses to external loading and act to resist excessive deformation to its natural lordotic shape (Bogduk & Yoganandan, 2001). Intervertebral discs and ligaments serve to absorb high forces at low impact velocities, while high velocities cause them to rapidly stiffen (Cusick & Yoganandan, 2002). Ligaments of the upper cervical spine are stronger in extension than the lower cervical spine, and the upper cervical spine is significantly more resilient when faced with external loading (Nightingale et al., 2007). This is thanks to the extensor dominant organization of the neck explained earlier. The size and organization of tissues in the neck have been dictated by the neck's extension dominant orientation in response to the forward orientation of the head relative to the cervical spine and an inherent need to cancel out the pull of gravity, with male necks typically greater in size and stiffness when compared to females due to their larger physical size (Nightingale et al., 2007; Nuckley et al., 2008).

No structure is built to withstand all situations. Major injuries are defined as those that cause structural problems which compromise stability and neural integrity (Cusick & Yoganandan, 2002). The crucial determinants of these injuries are magnitude ad vector of force as well as rate of force application (Cusick & Yoganandan, 2002). Injuries are more likely to occur when the neck endures high tensile forces or axial loading (down the axis of the spine) and shearing in the cervical spine (sometimes at the same time), leading to excessive loading and deformation of cervical structures (Yoganandan et al., 1996). The severity of injuries from these forces also increases with age as movement limitations worsen and tissue quality degrades. Regardless of age, however, the whiplash type injury (rapid acceleration followed immediately by rapid deceleration) can cause severe damage (Cusick & Yoganandan, 2002). High speed impacts are the most dangerous, as damage to neck structures can occur before the onset of reflexive neuromuscular action, thus before the muscles can respond to dissipate incoming forces (Swartz et al., 2005). An inability for people to be in a neutral head and neck position is thought to be an indicator of pathology and possibly lead to a predisposition to greater damage from high impact injuries (Cusick & Yoganandan, 2002; Strimpakos, 2011a). However, injury patterns are not solely dependent on mechanical structures; neuromuscular coordination must also be optimized to ensure adequate spinal stability. In the next section, neuromuscular coordination will be explained to better understand how muscles of the neck function in the greater physical system.

2.1.2. NEUROMUSCULAR CONTROL & FATIGUE

Proprioception is the sense of physical position in space (Grigg, 2016). The neck serves as an intermediary within the proprioceptive chain, bridging sensory input between the eyes (vision), ears (vestibular), and brain with the rest of the body's senses (Figure 4) (Vuillerme et al., 2005). Proprioceptive nerve endings are active predominantly when muscle tension is detected, with muscle spindle receptors being the most important during muscle stretch from overall movement (Strimpakos, 2011a). Deep neck muscles are unique as they possess higher than normal densities of muscle spindles (stretch detecting proprioceptors) in the dorsal and occipital muscles (stabilizers), which are thought to be the major source of neck proprioception (Gosselin et al., 2004). Afferent signals from muscle spindles and tendons contribute to joint position sense in active conditions but play no role when muscles are relaxed (Strimpakos, 2011a). When the body is attempting to maintain upright balance, the spine is constantly adjusting to postural disturbances, meaning there is a near constant inflow of information from the peripheral nervous pathways related to movement. When there is impairment to the neck muscles, the proprioceptive response is reduced, interfering with the afferent inflow of information and also reducing the neck's role in posture and stability (Gosselin et al., 2004).

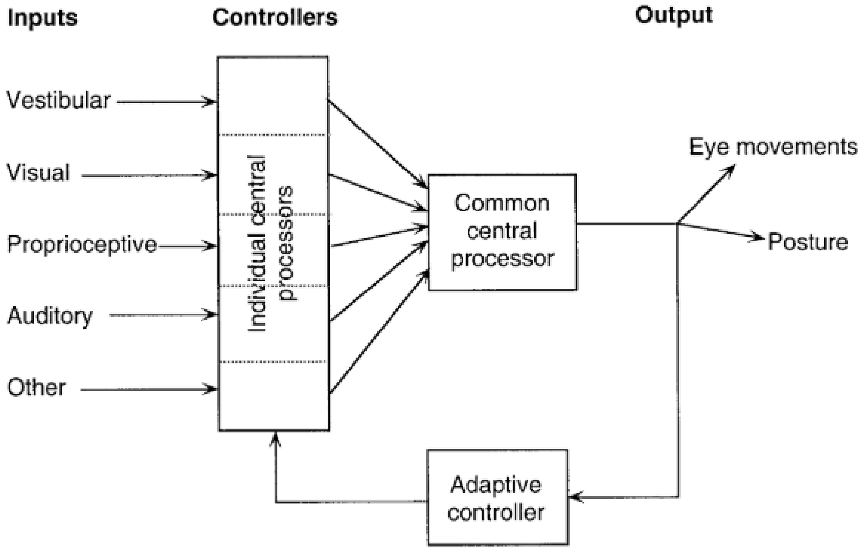

Figure 4: A schematic of sensorimotor integration with the brain (Halmagyi et al. 2003.)

All muscles typically require neural input for a contraction to occur, and research has shown that motor unit discharge in the neck is similar to other muscles in the body (Schomacher & Falla, 2013). Overall, neck muscles at rest require minimal muscle activation to maintain stability, with sitting postures requiring as little as 2-6% MVC in the deep and superficial muscles (Edmondston et al., 2011). At low levels of muscular demands, multiple neck muscles act together to produce the same movement, but when greater forces and higher loads occur at the neck, the muscles of the neck defer to the muscle responsible for that particular movement direction (such as the trapezius for extension) (Schomacher & Falla, 2013).

Fatigue is defined as an exercise-induced reduction in the ability to produce force or power whether the task can be sustained or not, and typically begins as soon as activity occurs (Enoka & Duchateau, 2008). Muscle fatigue leads to abnormal positioning and movement sense at the neck, leading to postural disturbances (Strimpakos, 2011a). This alters the signal output and information from proprioceptors in neck muscles, and is thought to be a source of disturbance in posture and balance (Liang et al., 2014). Although the neck can perform its role as a stabilizer with minimal requirements, deeper neck muscles are innervated with tonic gamma motor neurons making them highly sensitive to fatigue and the build-up of contractile metabolites, such as potassium ions, lactic acid, and arachidonic acid (Gosselin et al., 2004). These metabolites stimulate a positive feedback loop in the muscle spindles, causing more muscle activity to occur , not unlike other muscles in the body (Gosselin et al., 2004).

Regardless of age, sex, condition or muscle, neck dysfunction and “whiplash” type injuries lead to greater proportions of type IIC fibers in neck muscles (transitional or immature) (Uhlig et al., 1995). Muscles with type IIC fibers are highly susceptible to fatigue due to their reliance on glycolytic energy systems rather than the slow oxidative nature type I fibers that deeper neck muscles typically rely on (Olson et al., 2006; Uhlig et al., 1995). Higher levels of superficial muscle activation is an indicator of deeper disfunction or impairment (usually detected by low endurance or the increased presence of Type IIC fibers) (Jull & Falla, 2016; Schomacher & Falla, 2013). People with neck injuries or dysfunction tend to contract isometrically with more co-activation of superficial muscles, regardless of the direction of the force applied, when compared to asymptomatic people (Falla et al., 2004; Schomacher & Falla, 2013; Sterling et al., 2001). Because of this, muscle activation is typically more constant in those with chronic head & neck pain, which may contribute to difficulty maintaining endurance (Barton & Hayes, 1996). Fear, avoidance behaviour, and low endurance cause reduced muscle activation in deeper muscles, resulting in an increased stabilizing role for superficial muscles, a task they are not which they are not primarily suited for (Schomacher & Falla, 2013).

2.1.3. TESTING & NORMATIVE DATA

Assessment of the neck is important to understand performance levels, and possible dysfunction. Valid and reliable neck muscle endurance tests include the extensor and flexor endurance tests (Edmondston et al., 2008; Schieppati et al., 2003). The cervical flexion endurance test (CFET or craniocervical flexion test) is specifically designed to target the longus capitis and colli on the anterior aspect of the neck (also referred to as deep flexors) and requires the participant to lie supine while maintaining craniocervical flexion (Figure 5) (Jull et al., 2008). A difference between the two trials of more than 15 seconds typically warrants a third trial be done (Kumbhare et al., 2005; Olson et al., 2006). The CFET has been used to detect improvements in neuromotor control during study time frames of as little as 6 weeks (Nezamuddin et al., 2013). This test has been shown to have good to excellent intrarater reliability (ICC = 0.82-0.91) and moderate to good interrater reliability (ICC = 0.67-0.85) (Harris et al., 2005; Olson et al., 2006)

The cervical extension endurance test (CEET) is a test from Ljungquist et al., who created the test based on the Biering-Sorenson back-extension test (S. J. Edmondston et al., 2008; Ljungquist et al., 1999). This test has been found to be valid and reliable when comparing groups (SE of kappa = 0.109, 95% CI), but unlike the CFET, requires the use of a weight hanging from the head while prone with the body strapped down to ensure no trunk contribution during the isometric contraction (Gosselin et al., 2004; Sebastian et al., 2015). A similar test, requiring no added weight, has also been used to measure extension endurance, in addition to its declination over time (Sebastian et al., 2015). Both the flexor and extensor tests may be interfered with by the superficial muscles, such as the sternocleidomastoid, where larger muscles required for true extension or flexion may override postural muscles when they are not required (Edmondston et al., 2011). Reliability of these tests can be verified by performing the tests 3 times over a one week period (Strimpakos et al., 2005).

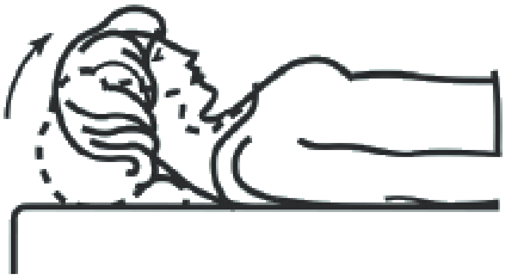

Figure 5: Craniocervical Flexion Endurance Test (Ornstein, 2020)

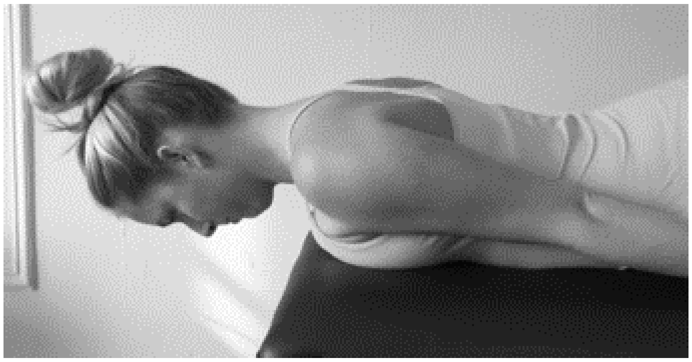

Figure 6: Cervical Extension Endurance Test (Smale & Rayner, 2016)

When testing neck endurance, it is suggested that participants be allowed to practice the chin tuck position (craniocervical flexion) for several seconds (Olson et al., 2006). A practice sequence described by Olson et al. (2006) used practice trials of 10 seconds with 30 seconds of rest between them. When in this position, some studies have used a blood pressure cuff placed under the occiput as a feedback tool for the participant to maintain 20mmHg pressure, or the placement of a hand just under the occiput (holding at about 2.5 cm above neutral resting) (Edmondston et al., 2008; Jull & Falla, 2016). In both cases, verbal encouragement is important, as the tests require maximal effort and do cause muscular discomfort (Edmondston et al., 2008). Testing is commonly monitored with the Borg CR-10 scale to help determine if maximal subjective exertion was reached, usually in conjunction with objective EMG measurements (Vuillerme et al., 2005). In spite of these two methods being used together frequently, Borg CR-10 ratings have been shown to have a weak correlation to EMG activity in the neck (Strimpakos et al., 2005).

Normative data for the CFET has been established with test times established at approximately 38.9 (±20.1) seconds for men and 29.4 (±13.7) seconds for women (Domenech et al., 2011). Subsequent studies have found that participants without neck pain typically last 40 (±25) seconds or more, and those with pain score 25 (±10) seconds, (Harris et al., 2005). Low CFET scores have been accepted as an indicator of dysfunction in deep neck flexors as explained in the previous section (Falla et al., 2004). Testing should be in an environment with minimal distractions, and strenuous activity avoided for 1-2 days before testing, to acquire the best results (Strimpakos, 2011a).

Individual neck muscle activity is difficult to measure due to their tightly packed organization and muscle overlap (Sniezek & Sofferman, 2012). Typical EMG protocols for neck extensor testing involves upper trapezius, using bipolar electrodes with 1mm distancing between electrodes, targeting the muscle bellies 2 cm from body midline and 4 cm below the cranial insertions (Schieppati et al., 2003). The EMG signal is usually amplified 1000-fold with a low pass filter cut off at 500Hz with the signal sampled at 1000Hz (Schieppati et al., 2003). During endurance testing, EMG is normally recorded for the first 10 second period of each minute of testing (Schieppati et al., 2003). Markers of true neck fatigue can be detected from a progressive increase in signal amplitude and decrease in signal frequency (Schieppati et al., 2003). Craniocervical flexion as well as an abducted arm appears to lead to the highest flexor and extensor EMG activity respectively (Schüldt, 1988). Median frequency shift during EMG measurement is accepted as the most useful method for objective measurement of neck function and fatigue (Gosselin et al., 2004). A decline of 9.5-18.9% in median frequency and an increase in amplitude has been shown to be a reliable marker of fatigue during voluntary contractions at the neck (Katsis et al., 2004). Examining median frequency EMG changes as a slope are effective for short isometric bursts but are not as effective for long lasting endurance bouts (Strimpakos et al., 2005). Much of the difficulty in testing with

EMG arises from the extreme difficulty in measuring neck neuromuscular activity without the use of invasive methods due to the compact overlap of muscle tissue (Rezasoltani et al., 2012).

In previous studies, inclusion criteria for participants who are asymptomatic to neck pain or dysfunction have included no complaints of pain, no symptoms of pain while joints are palpated, and no limiting injuries in the past year such as a concussion or whiplash. Exclusion criteria have included any history of spinal surgery, known cervical abnormalities or musculoskeletal issues, as well as any history of cancer or significant neck injury. Participants are also typically excluded if they have participated in a neck training program in the previous year (S. J. Edmondston et al., 2008; D. Falla et al., 2006). Participants are often screened using the neck disability index (which screens for the previously mentioned conditions) to determine if neck dysfunction is present (D. Falla et al., 2006). The target age range for most endurance testing is between 18-45 years of age, to exclude the effects aging may have on muscle function and proprioception (Field et al., 2008).

2.1.4. TRAINING THE NECK

Neck muscles have been shown to respond well to general strengthening and endurance training (Falla et al., 2006). Neck musculature is especially adaptable to training within the first few weeks, possibly due to neuromuscular coordination improvements, and can be trained in a periodized manner (Hanney & Kolber, 2007; Olson et al., 2006). It has been theorized that the level of neck endurance and strength attained at youth predisposes those same qualities later in life (Strimpakos et al., 2005). Even though muscle performance in the neck declines with age, as with other muscles, isometric qualities have been shown to stay relatively high well into old age regardless of sex (Chiu et al., 2002). The most commonly used methods of training the neck involve cervical flexion and extension repetitions (either resisted or unresisted) or isometric holds in flexion or extension (Falla et al., 2006; Hanney & Kolber, 2007). Studies typically build training programs that take 10-20 minutes of neck training 2-5 times per week over a 2 to 8 week period (Hanney & Kolber, 2007; Jull et al., 2007; O'Leary et al., 2007). Neck muscles respond especially well to strength training by increasing hypertrophy by 6-12% in about 8-12 weeks and is thought to help reduce the risk of injury and prevent neck pain. However, no widely accepted protocols have yet been established (Garces et al., 2003).

2.2. BALANCE

2.2.1. COMPONENTS OF BALANCE

Balance is considered a key motor skill in normal activities of daily living and can be expressed statically or dynamically (Ricotti, 2011; Vuillerme & Pinsault, 2009). The overall ability to maintain static balance (postural balance control) comes from coordination of the vestibular, somatosensory and visual systems, allowing the body to orient itself upright against gravity by interpreting the inflow of afferent information from these sensory inputs (Vuillerme et al., 2005). These systems receive sensory input from external disturbances and cause reflexive changes in the body against changes to body position which are sent to the central nervous system as afferent inflow (Figure 4) (Gosselin et al., 2004). The body uses these systems in combination, but to varying degrees. There is a notable preference to rely on the visual and somatosensory systems, with vision playing a more significant role in evaluating the body's upright position and posture (Gaerlan et al., 2012). It has been shown that the ability for vision to dominate balance control is reduced after whip-lash injuries to the neck (Hildingsson et al., 1989); this becomes especially true in aging populations, where vision typically worsens and tissues begin to lose elasticity and function (compared to younger populations), leading to alterations in balance (Abrahamova & Hlavacka, 2008; Halmagyi, 2003).

The somatosensory system plays a role in evaluating orientation about the base of support based on sensory disturbances from joints and tissues (Shumway-Cook & Horak, 1986). Development of this system comes into maturity early in life, around the ages of 3-4 (Steindl et al., 2006). There appear to be dominant proprioceptive strategies depending on stance. When feet are placed comfortably side-by-side, the body relies on somatosensory information from the ankles, feeding anterior and posterior disturbances, while the hips counteract medio-lateral disturbances (Winter, 1995). When feet are oriented heel-to-toe, the body reverses these strategies, whereby the ankles counteract medio-lateral disturbances and the hips, anterior and posterior ones (Winter, 1995). The vestibular system continues to develop until about 15-16 years of age, and functions to create biological signals from forces acting on the head in order to stabilize, but can be overridden by vision (Halmagyi, 2003; Steindl et al., 2006).

The central nervous system is actively processing input from the different senses, each providing information about a possible shift from postural stability or base of support (Balasubramaniam & Wing, 2002). Balance can be both static (standing or sitting in place) & dynamic (walking or running), with influence from feedforward and feedback neural control mechanisms (Mehta et al., 2010). These mechanisms allow the human body to maintain a stable base of support and allow for anticipatory or pre-planned muscle activation known as anticipatory postural adjustments against an anticipated perturbation, or generating a reflexive response to a disturbance (Bouisset & Do, 2008; Ricotti, 2011; Mehta et al., 2010). This system can be augmented through learned movement and behaviour patterns from past or similar experiences to a given situation influencing the anticipatory or reflexive decisions available (Bouisset & Do, 2008). These mechanisms can be trained and improved, allowing for active counterbalancing against disturbances to the body or from limb movement, meaning the body can become more efficient at maintaining balance when faced with a variety of disturbances or challenges (such as taking a step or reaching forward with an arm) (Balasubramaniam & Wing, 2002; Mehta et al., 2010). A unique study looking at the effects of balance training on postural neck pain showed a reduction in neck pain and improved cervical coordination after 5 weeks of balance training. This alludes to the possibility that the neck is involved in the feedforward and feedback mechanisms of balance, and neck training may improve balance performance (Beinert & Taube, 2013).

There are several conditions which can alter overall balance function. These typically affect major centers of balance control, such as vestibular issues from the inner ear (labryrinthitis and Meniere’s disease), vision problems, and interference with joint and muscle proprioceptive tissues through degradation (either damage or injury) (Sturnieks et al., 2008). Other issues arise from a failure to integrate sensory information via neural injuries or disorders, such as spinal cord injuries, Parkinson’s disease, strokes, traumatic brain injuries, and peripheral neuropathies from conditions such as unmanaged diabetes, brachial plexitis and many others (Schoneburg et al., 2013; Turcot et al., 2009). Although issues from the previously mentioned disorders/injuries can be debilitating and difficult to manage, the leading causes of neuropathy and spinal cord injury comes from automobile accidents and falls (Patek & Stewart, 2020). The latter has significant implications for balance management, especially in the aging population. Although there are many issues that affect balance which are difficult to prevent or manage, may be possible to increase quality of life through improved balance control.

2.2.2. BALANCE ASSESSMENT

Stabilometry is the study of body sway during quiet standing, typically without disturbance or voluntary movement (Kunihiro, 2014). Balance assessments used to date come in many forms, utilizing a variety of measurement tools and techniques. The accepted “gold-standard” tool typically used for balance testing is a laboratory force plate, regardless of testing technique used (Clark et al., 2010; Kunihiro, 2014; Shieh et al., 2020). In most studies, measurement tools are either compared against, or used in conjunction with force plates, however these devices require a high cost and are generally impractical outside of a testing or lab setting (Shieh et al., 2020).

There are alternative measurement techniques for balance, including accelerometry and motion analysis (Kamen et al., 1998; Kejonen & Kauranen, 2002). Accelerometry utilizes small sensors attached to the body to detect changes in acceleration, providing acceleration specific information about movement (which velocity can be derived from), but can be costly to acquire and require expertise to operate which has led to an increased use of smart-phone based accelerometry research (Hsieh & Sosnoff, 2021; Ojie & Saatchi, 2020). Motion analysis utilizes infrared markers and cameras to build a three-dimensional model of the body or limbs while they undergo movement, allowing for the calculation of limb or joint specific angles, velocities and accelerations (Kejonen & Kauranen, 2002). Both of these methods of measurement allow for more specific analysis of the body when comparing body or limb motions and have been used as valid alternatives to force plates (Hsieh & Sosnoff, 2021; Kejonen & Kauranen, 2002; Shieh et al., 2020).

Stabilometry tests are well suited for observations of whole body sway by measuring center of pressure (COP) and center of pressure velocity (COPV) as an average, which is one of the more reliable and valid ways to measure quiet standing balance, especially in study designs with multiple measurement trials and timepoints (Barbado et al., 2017; Clark et al., 2010; Kunihiro, 2014). While COPV is the best choice for measuring postural balance, other reliable and viable methods of characterizing center of pressure data include the convex hull method, principle component analysis, mean of circle areas, and root mean square (RMS) distance (Lin et al., 2008; Wollseifen, 2011). In the convex hull method, sway is characterized by calculated the area within the sway trajectory as an approximation. Principle component analysis is used to create an ellipse around the sample data. The mean of circles looks at the distance each sample point is from the origin point, whereas the RMS method looks at the average distance between data points (Lin et al., 2008).

There are a variety of quiet standing tests utilized to assess balance performance, several of which were designed to assess balance or identify potential vestibular or proprioceptive disorders. These tests challenge dynamic or static stability, anticipatory and reactive postural control, functional stability limits, sensory integration and cognitive or attentional influence (Arora et al., 2020). Common tests and testing batteries include the Romberg (basic vestibular test), Single Leg Stance (dynamic challenges to single leg stability), the Balance Evaluation Systems Test or BESTest (and the shorter mini-BESTest, both a battery of tests), the Balance Error Scoring System (BESS, similar to the tests used in this study), the Tinetti POMA test (a battery of tests) (Canbek et al., 2013; Chinsongkram et al., 2014; Finnoff et al., 2009; Kim et al., 2012; Yingyongyudha et al., 2016).

Many of these tests are used in clinical populations to assess changes in balance performance, however not all of them solely rely on standing balance measurements and can be considered more dynamic in nature compared to more simple tests such as the BESS of each of the BESS's individual tests. Based on the tests available, the components of the BESS test were selected based on their practicality and ease of use along with the use of a force plate to increase its validity and reliability. Quiet standing tests were chosen to allow for any postural changes from an intervention to be isolated more easily compared to tests that require significant movement. A key factor is the use of a visual cue or target during tests such as the Romberg, as vision serves as a major contributor of balance control (to avoid physical drift from gaze drift). Visual cuing essentially provides a control against postural drifting from the vestibular system, allowing changes in balance to be considered postural/proprioceptive and visual (Kysar & Dalton, 2019).

2.2.3. NECK INFLUENCE ON BALANCE

Cervical receptors play a key role in central and reflex connections to vestibular, visual, and postural control which make it a significant intermediary for sensory information from the peripheral and central nervous systems (Field et al., 2008). Balance diminishes when the neck has undergone trauma or when significantly fatigued, as demonstrated by alterations in center of pressure distribution (Field et al., 2008; Gosselin & Fagan, 2014; Liang et al., 2014). Neck function can also be affected by posture, movement, eyes being open or closed, and quality of spinal control (Strimpakos, 2011a). Abnormal signals due to changes in proprioception at or passing through neck muscles cause a type of "cervical vertigo" where balance is altered because information is not being relayed properly through the proprioceptive chain to the brain and spinal cord (Schieppati et al., 2003). Altered somatosensory input and integration can come from direct trauma to receptors as well as impairment of muscle and joint receptors; inflammation may also directly alter spindle activity (Field et al., 2008). These changes can be seen during low level maximal voluntary isometric contractions in muscles such as the neck extensors (at approximately 25% of maximum), leading to significant changes in balance at lower median EMG frequencies (fatigue) (Gosselin et al., 2004). Atrophied neck muscles (typically through dysfunction or inactivity) also appear to cause a reduction in proprioceptive performance during balance (McPartland et al., 1997).

Studies show that simulated pain and intentional vibration over the neck muscles has a greater influence on postural control than elsewhere in the body, suggesting that dysfunction and injury to the neck significantly alter proprioception (Field et al., 2008; Vuillerme & Pinsault, 2009). Direct vibration on the neck causes center of pressure changes and increased sway in the direction opposite to the source of vibration (Schieppati et al., 2003). Uniquely, neck vibration during stepping in place causes a person to rotate towards the contralateral side (Schieppati et al., 2003). Vibration studies effectively highlight the importance of neck musculature in maintaining posture and spinal stabilization during balance and that it plays a constant role in counteracting gravity.

Based on the literature available, it appears that deep neck muscles may serve as an adaptive controller for balance function by influencing postural control and the reflexive or anticipatory mechanisms of balance (Vuillerme & Pinsault, 2009). This can be seen when neck muscles sustain fatigue or damage, leading to significant balance disturbances (Gosselin & Fagan, 2014; Vuillerme et al., 2005). There appears to be a dichotomy between functions of the layers of neck muscles with the superficial and larger muscles providing structural stability and support for the cervical spine as prime movers for the head (Blouin et al., 2007). The deeper muscles on the other hand, appear to play a key role in spinal stability, predominantly assisting and influencing postural control (Blouin et al., 2007; Gosselin & Fagan, 2014). In Gosselin & Fagan's study (2014) the extensors were fatigued for fifteen minutes at 35% of maximal voluntary isometric contraction and showed large disturbances in posterior-oriented sway patterns (shifting back over the heels after extensor fatigue). In contrast when the flexors were fatigued (same fatigue protocol) the sway pattern was insignificantly changed and maintained over the base of support with only a slight anterior trend.

This outcome seems to highlight a higher affinity for resistance to fatigue in the flexor group during isometric endurance. Neck muscles follow the size principle like all muscles, where larger prime movers have preferential recruitment, and then muscle contractions "downshift" as type II fibers in prime movers are fatigued, leading to smaller muscles (deep neck muscles) which are typically type I fibers and more resistant to fatigue (Holt et al., 2014). Despite Gosselin & Fagan (2014) applying the same fatigue protocol for flexion and extension (using median EMG frequency shift to objectively identify fatigue), the response in the extension direction implies that the deep extensors are less able to withstand fatigue compared to the flexors. Interestingly, the deep extensors possess up to 100 times more muscle spindles than the superficial trapezius, indicating that they may work in synergy with deep flexors for cervical postural control (Gosselin & Fagan, 2014). Due to the complex synergies present in neck muscles, it remains difficult to determine what influence the deep extensors have over postural control; based on their structure and locations, they may serve more of a role for head and neck movement control rather than spinal stability (Bogduk & Mercer, 2000; G. A. Jull & Falla, 2016). It is possible that the endurance capabilities in these muscle groups allows for balance control to be maintained from a cervical spine perspective.

2.3. SUMMARY

Current neck and balance literature provides an opportunity to explore whether neck endurance can affect standing balance. It has been shown that the neck is sensitive to fatigue, but also highly trainable through simple methods of exercise. The role that the neck plays as a conduit for sensory information and motor control establishes its importance for overall body stability and function, however there is no clear path between directly training the neck and improvements in balance. While it has been shown that neck training both improve neck endurance and function, what is less clear is if balance will be affected by specifically training the neck. This study aims to improve on the current literature base by exploring this question.

3. METHODOLOGY

See Figure 7 for a schematic representation of the following study design.

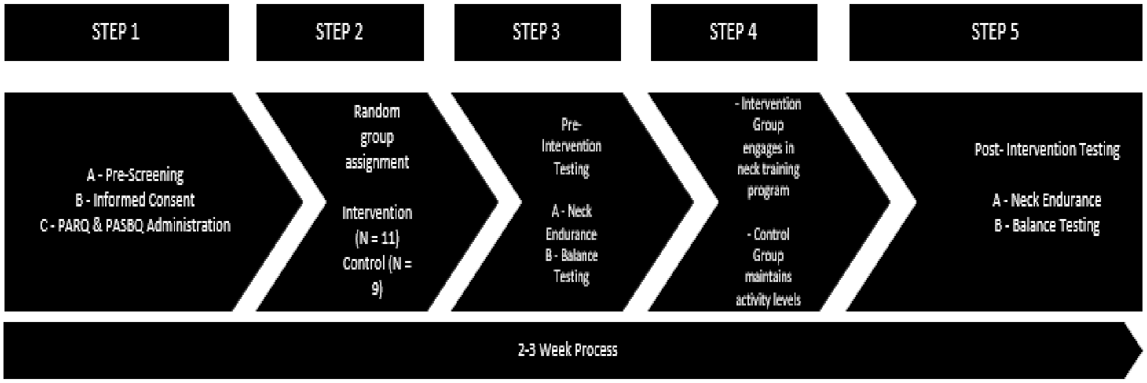

Figure 7: Schematic Representation of the Study Design

3.1. RECRUITMENT

3.1.1. TARGET POPULATION

Participants were recruited from the City of Halifax, and the town of Wolfville, in Nova Scotia, Canada. A previous neck flexion endurance study run by the co-investigator was used to determine that a sample size of 16-24 participants was required to achieve statistical power (above 0.9). In that study, 24 participants were recruited and large improvements in spine muscle endurance was seen over a 6-week period (38 – 42%) (Moreside & McGill, 2012). Other studies similar in nature utilized similar sample sizes ranging from 10-30 participants (Gosselin et al., 2004). This study recruited each sex in even numbers, selecting apparently healthy youth and adults between the ages of 18-64 (as defined by Statistics Canada) that were capable of legally consenting without a guardian. In total, 22 participants were recruited, but 2 participants were removed because of incomplete data. One of the incompletions was due to a time conflict with other commitments, while the second one was removed because they were unable to complete the post-intervention testing within the study timeframe.

Recruitment was done using a recruitment poster, whereby the prospective participants used the contact information provided to learn how to get involved with the study, via email/phone, with some participants recruited through word of mouth. Once the participants had been recruited, they were sent copies of all necessary screening and consent forms via email. After agreeing to participate and completing the preliminary screening process, participants were randomly assigned to the control or intervention group using a block randomization method to ensure sexes were evenly distributed across both groups.

- Participants were grouped as follows:
    - Intervention Group : 11 participants (5 males, 6 females)
    - Control Group: 9 participants (5 males, 4 females)

3.1.2. SCREENING & SELECTION

Exclusion Criteria

Participants were screened for physical readiness (PARQ+) and current activity levels (PASBQ) (Appendix A & B, respectively). These forms were used to screen participants for general readiness for physical activity (including dizziness and concussion related injuries) and assess their typical daily activity levels to see if changes in physical activity occurred throughout the study. The primary investigator is a certified exercise physiologist through CSEP-CEP and these forms are used before most physical activities in practice. The PARQ+ and PASBQ were administered once at the beginning of the study, then the PASBQ was also administered at the end of the study to determine if physical activity behaviors had changed in any meaningful ways that may have affected physical performance (such as a spike in resistance training, for example). Exclusion criteria included conditions that adversely affected neck and balance performance either acutely or chronically within 6-12 months prior to study participation (Appendix C). Any prospective participants that had an injury history or condition that significantly affected balance was excluded. Examples include concussions, neurological impairments and damage, vision problems, balance disorders and musculoskeletal injuries that permanently impaired normal body function. All screening questionnaires can be found in Appendixes A-C.

Screening Process

1. Participants were sent/given the consent form for the study as well as a copy of the PARQ+ and the screening questionnaire (Appendix C).
2. If participants were ineligible to participate, they contacted the research team and notified them, but did not have to specify a reason.
3. If they could participate, they returned the completed forms.
4. Following this, participants were asked to complete PASBQ to establish their physical activity habit baseline.

3.1.3. METHODS

3.1.3.1. Paper Flyers

These were placed in approved and common locations around campuses.

- Appendix D: Flyer used and placed around the Dalhousie campus.

3.1.3.2. Digital Recruitment

This was done primarily through email. Promotional information was sent out to key administrators to attract prospective participants.

- Appendix E: Email template

3.1.3.3. Word-of-Mouth recruiting

This method was used to promote the study and draw in prospective participants. The goal of this was to get prospective participants talking about the study and sharing recruiting information with other people who may be interested. Follow-ups to inquiries were given using the email template mentioned (Appendix E).

3.1.4. CONSENT

Written consent was necessary for participation in the study, and participants were informed they could remove consent at any time. Written consent on the consent form was provided by participants before any personal information was obtained; such information was limited to only that deemed pertinent to the study design. Participants were able to email or phone the investigators to ask any questions before they provided their signed consent form (Appendix F) and were informed that they had the right to withdraw consent at any time.

Participants received oral and written instructions from the lead investigator, outlining all testing procedures involved (Appendix F). Written consent was given only after all participants' questions regarding the study had been satisfied (via phone, email or in person). Before each test in the study, the lead investigator asked the participant if they understood the instructions provided, and whether they required further clarification. Participation was voluntary, with no obligation to continue should they decide to withdraw.

3.1.5. DATA STORAGE

Data was stored both digitally and physically. All paper forms were kept in locked cabinets in the supervising professor's office which were only accessible to the professor, with any descriptive information of participants recorded onto locked digital files, only accessible to the principal investigators. All participants were given a non-identifiable designation that their data was listed under.

3.2. ANTHROPOMETRIC MEASUREMENT

On the first day of participation, testing began with anthropometric testing. Anthropometric measurements included age, sex, body height and weight as well as neck girth and length (Gosselin et al., 2004). This provided information about the participants to better describe and compare their results. Neck measurements would show if changes had occurred to neck girth throughout the study, which could infer that neck hypertrophy had taken place. Age and sex were self reported, while unshod height and bodyweight was measured using a stadiometer and weight scale. Neck measurements were taken with an anthropometric measuring tape, with neck height measured from the spinous process of the T1 vertebra to the occiput of the base of the skull, and girth was taken just under the jawline and occiput (but above the "Adams apple" for males) (Norton, 1996). Measurements were taken before and after the 2-week intervention.

3.3. NECK ENDURANCE TESTING

Following anthropometric testing, neck endurance was measured using valid and reliable protocols for neck flexion and extension (Harris et al., 2005; Ljungquist et al., 1999). Flexion was measured with the participant lying supine on a plinth. Each participant adopted a chin-tuck position with a slightly raised the head off the plinth, with the examiners hand just below the occiput. Each participant was given 2 practice trials of 10 seconds (with 30 seconds rest between each) to become familiar with the testing position (Olson et al., 2006). When the test began, participants were motivated to hold the position for as long as possible, without touching the examiner's hand (Figure 5). If the participant failed to stay off the examiners hand, or lost the chin-tucked position, the test was over. All trials were measured for time in seconds to a maximum of 2 trials. The neck extensor test required each participant to lie prone on a plinth with their arms by their sides, adopting the same chin-tuck position as the flexion test (Figure 6). Participants received the same practice trial guidelines explained earlier. Participants were motivated to hold their head in the neutral (horizontal) position for as long as possible. During the test, any changes to head inclination as demarked with a vertical ruler ended the trial. Trials were measured for time in seconds.

Both tests were completed for maximum time, with verbal encouragement given to each participant to hold the positions for as long as possible. Two trials were done for each test, with 3 minutes of rest between each trial, and 5 minutes of rest between each test. To determine subjective effort, the Borg CR-10 scale was asked after each trial as seen in Appendix G.

3.4. BALANCE TESTING

3.4.1. BALANCE ASSESSMENT

Balance was measured using AMTI force plates to evaluate stabilometry, specifically, center of pressure data which allowed for the calculation of center of pressure displacement, as well as center of pressure mean velocity changes (described in section 3.6). These two measurements are reliable measures of balance performance with several studies reporting intraclass correlations (ICC's) of mean velocity between 0.75 and 0.9 which is defined as good reliability (Kouvelioti et al., 2015; Lin et al., 2008). All tests required the participant to cross their arms over their chest and were given a visual target at eye level (tripod with a marker against a plain background) to mitigate vestibular influence, falls or deliberate balance drift. The auditory environment was controlled by restricting access to the testing area during data collection to ensure there were no auditory interruptions or disturbances. Participants completed a battery of balance tests, including the Romberg (ROM, feet parallel), the Modified Romberg (MROM, dominant foot forward, heel-to-toe with the back foot), and unipedal stance tests (UL & UR, done on both the left and right side, individually). All balance tests were completed with eyes opened (EO) and eyes closed (EC). These balance tests were chosen because of their clinical simplicity in detecting proprioceptive changes or impairments in order to allow for future researchers to easily replicate and utilize the tests from this study in a practical setting (Murray et al., 2014). The Romberg test requires low-technology, and can be done with eyes opened and closed, and is found to be valid and reliable when inter-tester reliability is consistent (Murray et al., 2014). This test is strengthened when used in conjunction with a force plates to evaluate sway (Kim et al., 2012). Single leg balance testing (UR & UL) has been found to be a challenging but reliable test for measuring balance (Yi et al., 2014). All tests have been found to be moderate to highly reliable in test-retest reliability, with double leg tests providing higher reliability with ICC's falling between 0.67 and 0.95 (Kouvelioti et al., 2015).

Each participant was instructed on how to perform each balance test and were given time to familiarize themselves with the stances. Participants completed three each of eyes-open and eyes-closed trials for each test. Romberg and Modified Romberg balance tests had a maximum of 60 seconds, and a maximum of 45 seconds was used for the single leg tests. The trial was restarted if the participant lost balance (falling or a significant break in upright posture) within the first 5 seconds, with a maximum of 2 restarts. Participants went through their balance testing using the counterbalancing method, whereby the sequence of balance testing was randomized. All balance testing was done after a full rest period of 10 minutes within the same day as neck endurance testing.

3.5. TRAINING INTERVENTION

The training intervention included 6 sessions over 2 weeks (Table 1). Training took no more than 1 training minute, 3 days per week. Training required participants to hold the chin-tucked position in flexion and extension, with time increasing progressively throughout the program. No external implements were required. Extension holds were completed while prone, and flexion while supine. A copy of the program can be found in Tables 1 & 2.

Table 1: Overall Training & Testing Schedule Example

Week	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
1					*Pre-Intervention Testing*
2	*Intervention Day 1*		*Intervention Day 2*		*Intervention Day 3*
3	*Intervention Day 4*		*Intervention Day 5*		*Intervention Day 6*

Week	Monday	Tuesday	Wednesday	Thursday	Friday
4	*Post Intervention Testing*				

Table 2: Weekly Breakdown of the Training Program. Each session is done 3x/week. Rest can include endurance training for the other side of the neck, making this a circuit.

Week	Sets	Flexion Hold	Extension Hold	Total Time
1	2	10 s	10s	40 sec
2	3	10 s	10s	60 sec

3.6. DATA MEASUREMENT & STATISTICAL ANALYSIS

Data was collected using an AMTI force plate. The code used for acquisition and processing was created by the researchers and can be found as Appendix H. The code was written to calculate forces and moments in the XYZ planes from voltage changes, which were collected at 1000Hz, then low pass filtered using a 4th order Butterworth filter (cut-off of 5 Hz) (Prieto et al., 1996). The data was saved to a structured array for processing within MatLab (version 9.2.0.556344, R2017a; Natick, Massachusetts, USA) to convert voltages to forces and moments. The data was calibrated using the specific gain matrix and calibration matrix for the force plate to determine the forces and moments. The gain was set to 2000. This data was then used to calculate COP positional data in centimeters and further converted into velocity by calculating the derivative. The code was written to process each trial automatically as they occurred. To analyze COPV measures, values were averaged for each test condition for analysis.

Data analyses was completed using SPSS (version 26, 2019, IBM Corp; Armonk, New York, USA) on all participant trials. 2x2 mixed ANOVAs were performed on the dependent variables, with post-hoc t-tests run to characterize any significant interactions or effects comparing an intervention and control group prior to and after a two-week training intervention. The dependent variables within this study are neck endurance measures (CFET, CEET) and COPV balance measures (ROM, MROM, UL, UR, all with eyes open or eyes closed).

4. RESULTS

Anthropometric measures of study participants are presented in Table 3, and neck endurance and balance data for the study participants are presented in Table 4. The ANOVA for CFET presented a significant main effect for timepoint of (F(1,17) = 8.135, p = 0.011, partial η^2 = 0.324), a non-significant main effect for group (F(1,17) = 103.206, p = 0.056, partial η^2 = 0.199), and a significant interaction effect between timepoint and group (F(1,17) = 10.614, p = 0.005, partial η^2 = 0.384) (Figure 8). An independent samples t-test determined that there was no significant difference prior to the intervention (t (17) = 0.023, p = 0.982) but there was significant improvement in CFET in the intervention group (101.2 ± 43.8 seconds) after the neck training intervention compared to no significant change in the control group (49.9 ± 25.9 seconds), t(18) = -2.936, p = 0.009.

Table 3: Participant Anthropometrics. Results represent group means ± standard deviation.

Group	**Height** (m)	**Mass** (kg)	**BMI** (kg/m^2)	**Neck Girth** (cm)	**Neck Length** (cm)
Control	1.7 ± 0.1	74.6 ± 18.8	25.1 ± 3.5	33.2 ± 3.7	12 ± 2.38
Intervention	1.7 ± 0.1	82.5 ± 24.5	27.6 ± 6.0	33.7 ± 5.7	11.6 ± 2.12

An ANOVA was run for CEET and presented a non-significant main effect for timepoint (F (1,9) = 0.640, p = 0.444, partial η^2 = 0.066), a non-significant main effect for group (F (1,9) = 0.995, p = 0.345, partial η^2 = 0.100), and a non-significant interaction between timepoint and group (F (1,9) = 5.026, p = 0.052, partial η^2 = 0.358) (Figure 9).

ANOVA testing for ROMEO presented non-significant main effects for timepoint (F (1,18) = 2.464, p = 0.134, partial η^2 = 0.120) as well as group (F (1,18) = 28.461, p = 0.159, partial η^2 = 0.107). The interaction between timepoint and group for ROMEO was also non-significant (F (1,18) = 1.177, p = 0.292, partial η^2 = 0.061) (Figure 10). ANOVA for ROMEC showed a non-significant main effect for timepoint (F (1,18) = 1.630, p = 0.218, partial η^2 = 0.083), but a significant main effect for group (F (1,18) = 4.891, p = 0.04, partial η^2 = 0.214), and a non-significant interaction between timepoint and group (F (1,18) = 3.185, p = 0.067, partial η^2 = 0.175) (Figure 11). The intervention group showed a non-significant change from the intervention.

ANOVA results for MROMEO COPV showed non-significant main effects for timepoint (F (1,18) = 0.059, p = 0.811, partial η^2 = 0.003) and group (F (1,18) = 0.606, p = 0.446, partial η^2 = 0.033), and a non-significant interaction effect between timepoint and group (F (1,18) = 0.660, p = 0.427, partial η^2 = 0.035) (Figure 12). ANOVA results during MROMEC showed a significant main effect for timepoint (F (1,17) = 8.381, p = 0.010, partial η^2 = 0.330), a non-significant main effect for group (F (1,17) = 0.002, p = 0.968, partial η^2 = 0.000), a non-significant interaction effect between timepoint and group (F (1,17) = 0.041, p = 0.841, partial η^2 = 0.002) (Figure 13).

ANOVA results for ULEO COPV showed non-significant main effects for timepoint (F (1,18) = 0.342, p = 0.566, partial η^2 = 0.019) or group (F (1,18) = 1.223, p = 0.283, partial η^2 = 0.064), and a non-significant interaction effect (F (1,18) = 1.775, p = 0.199, partial η^2 = 0.090) (Figure 14). ANOVA results for ULEC showed non-significant main effects for timepoint (F (1,17) = 3.709, $p = 0.071$, partial $\eta^2 = 0.179$) or group (F (1,17) = 1.696, $p = 0.210$, partial $\eta^2 = 0.091$), and a non-significant interaction effect (F (1,17) = 0.015, $p = 0.903$, partial $\eta^2 = 0.001$) (Figure 15). ANOVA results for UREO showed non-significant main effects for timepoint (F (1,18) = 0.589, $p = 0.453$, partial $\eta^2 = 0.032$) or group (F (1,18) = 0.603, $p = 0.447$, partial $\eta^2 = 0.032$), and a non-significant interaction effect (F (1,18) = 0.050, $p = 0.826$, partial $\eta^2 = 0.003$) (Figure 16). ANOVA results for UREC showed non-significant main effects for timepoint (F (1,18) = 1.326, $p = 0.265$, partial $\eta^2 = 0.069$) or group (F (1,18) = 0.002, $p = 0.968$, partial $\eta^2 = 0.000$), and a non-significant interaction effect (F (1,18) = 1.173, $p = 0.293$, partial $\eta^2 = 0.061$) (Figure 17).

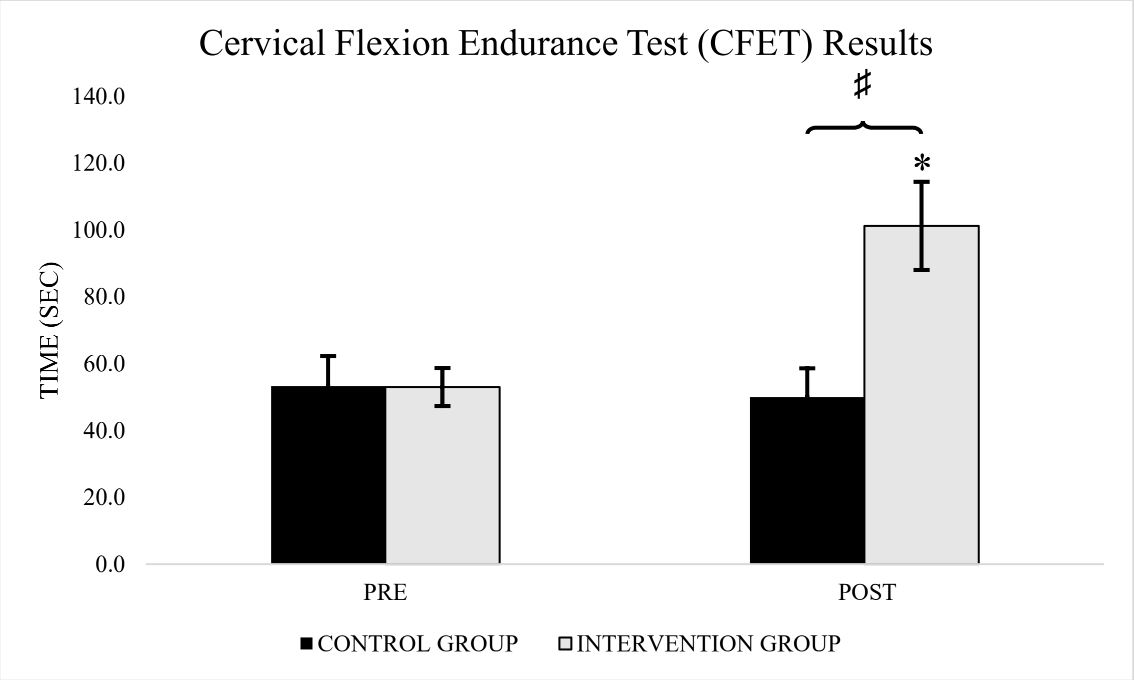

Figure 8: Cervical Flexion Endurance Test (CFET) Results, comparing a control and intervention group across the two-week training intervention for neck endurance. ♯ = Intervention group significantly different from control group at post-test ($p \leq 0.05$), * = Intervention group significantly different from pre-test to post-test ($p \leq 0.05$).

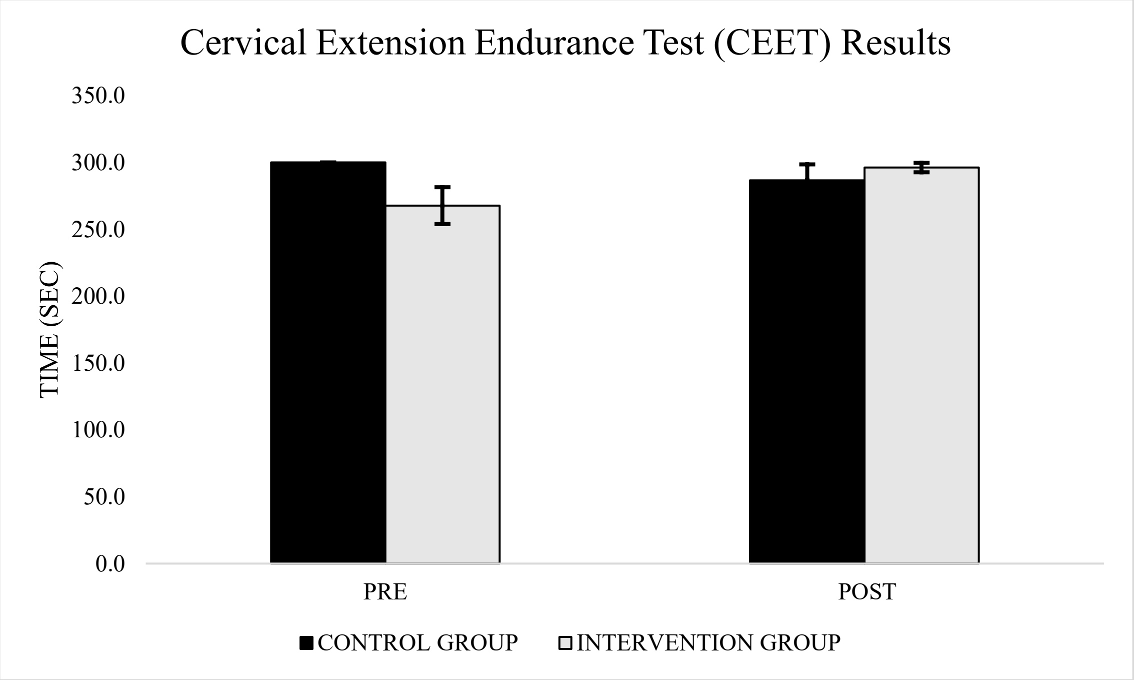

Figure 9: Cervical Extension Endurance Test (CEET) Results, comparing the control and intervention group across the two-week training intervention for neck endurance.

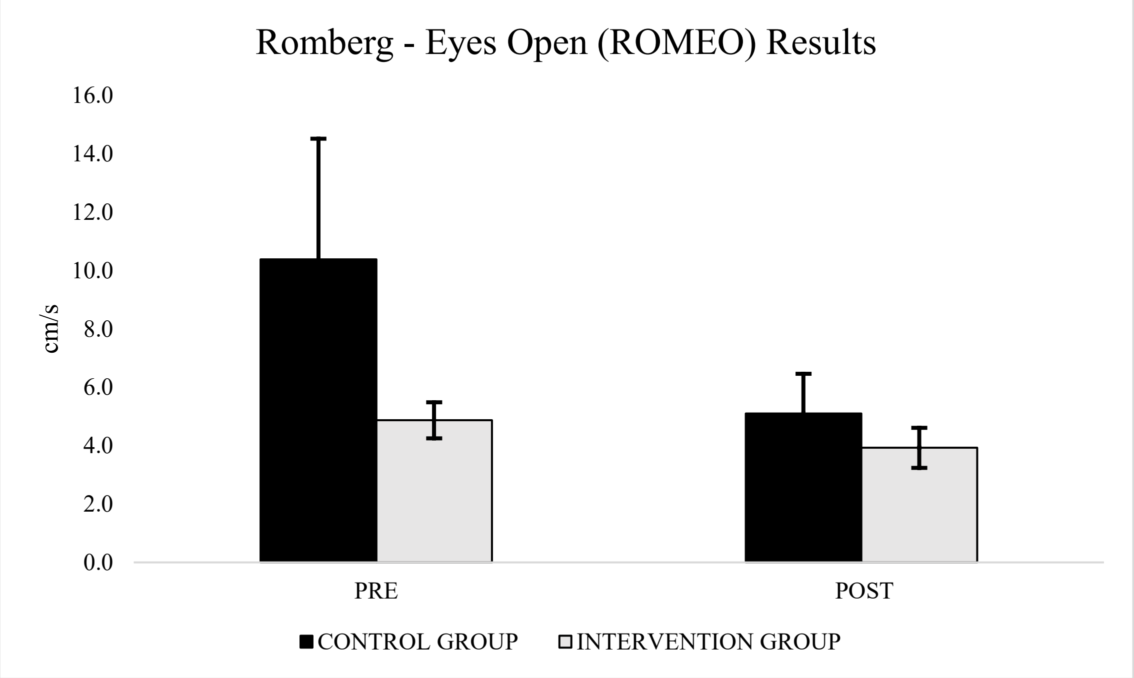

Figure 10: Romberg - Eyes Open (ROMEO) Results, comparing average sway velocity (COPV) during two-foot parallel stance with eyes open between the control and intervention group across the two-week training intervention.

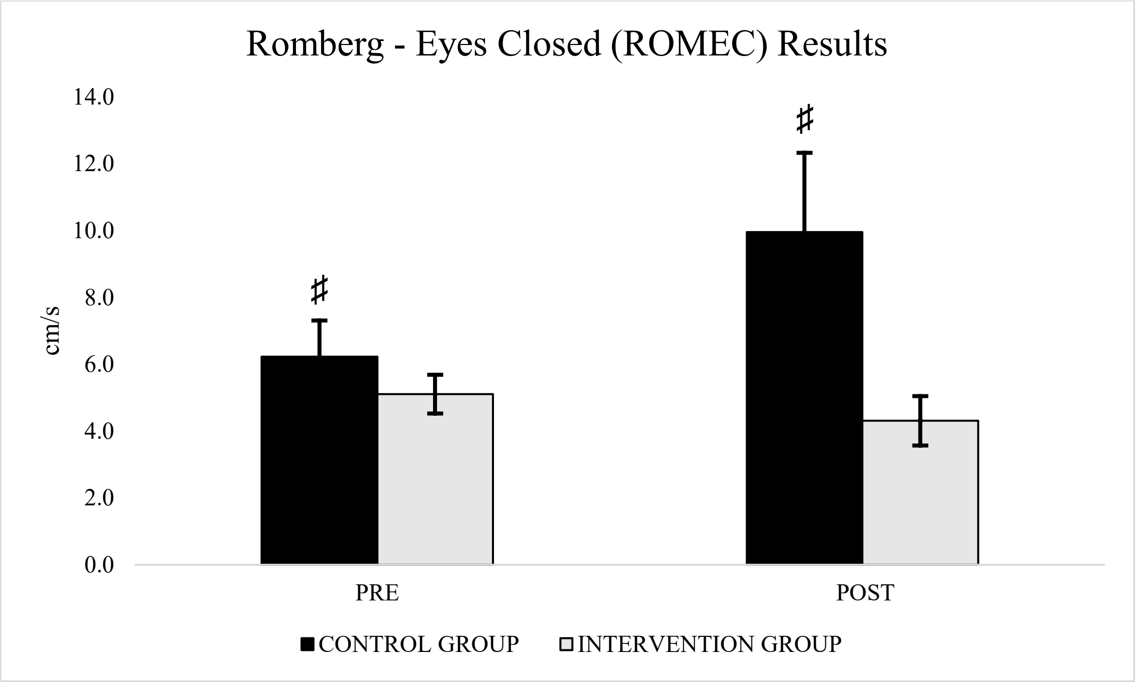

Figure 11: Romberg - Eyes Closed (ROMEO) Results, comparing average sway velocity (COPV) during two-foot parallel stance with eyes closed between the control and intervention group across the two-week training intervention. ♯ = Significant main effect for group ($p \leq 0.05$).

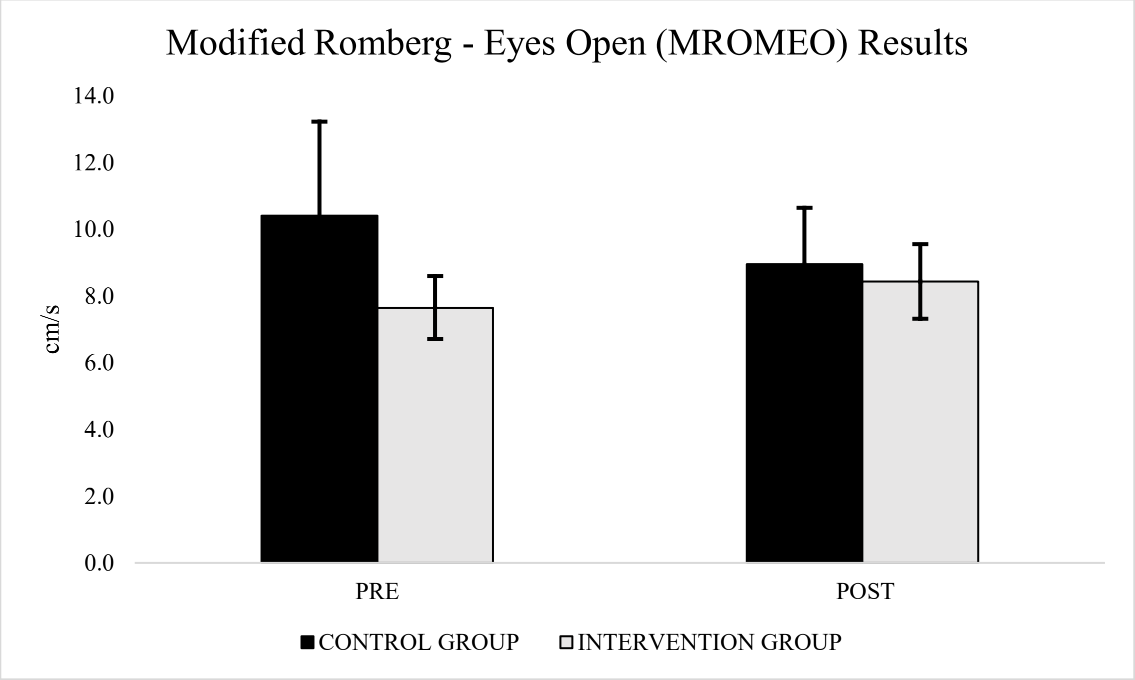

Figure 12: Modified Romberg - Eyes Open (MROMEO) Results, comparing average sway velocity (COPV) during the two-foot tandem stance with eyes open between the control and intervention group across the two-week training intervention.

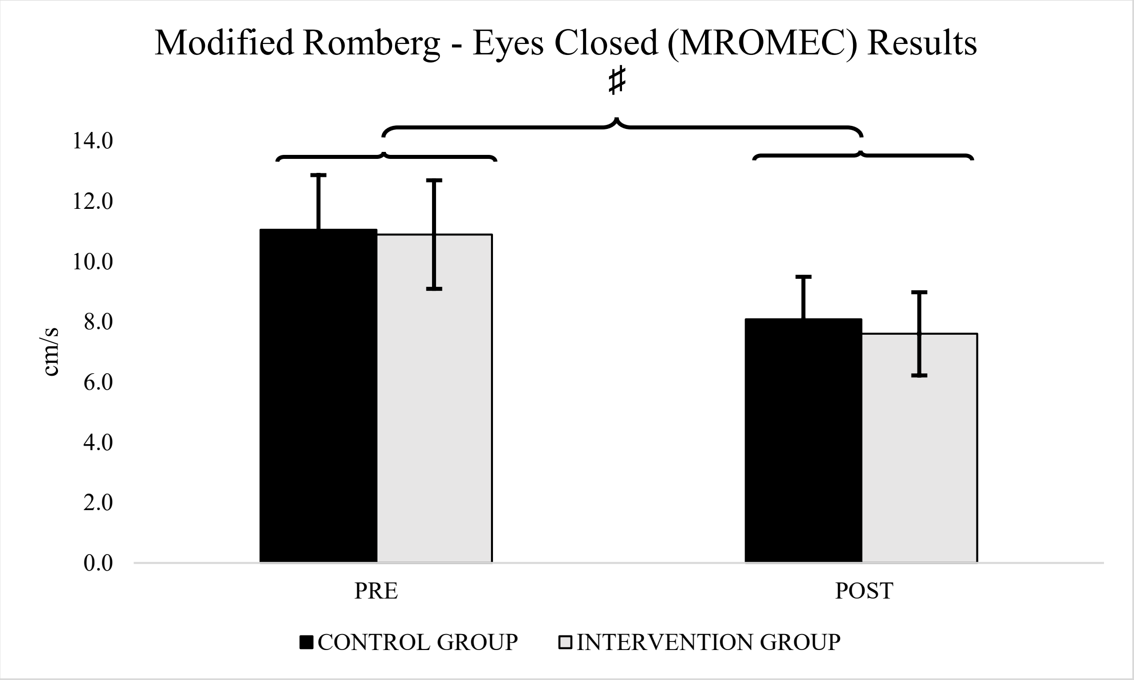

Figure 13: Modified Romberg - Eyes Closed (MROMEC) Results, comparing average sway velocity (COPV) during the two-foot tandem stance with eyes closed between the control and intervention group across the two-week training intervention. ♯ = Significant effect for time point ($p = 0.01$)

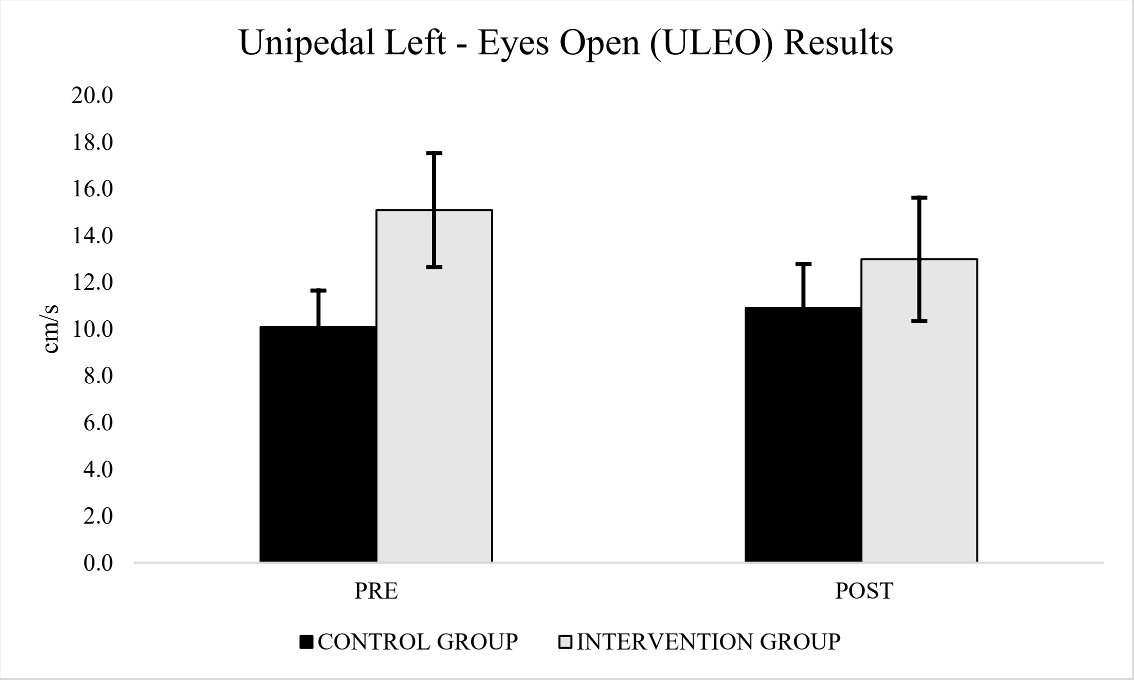

Figure 14: Unipedal Left - Eyes Open (ULEO) Results, comparing average sway velocity (COPV) during the single leg left-side stance with eyes open between the control and intervention group across the two-week training intervention.

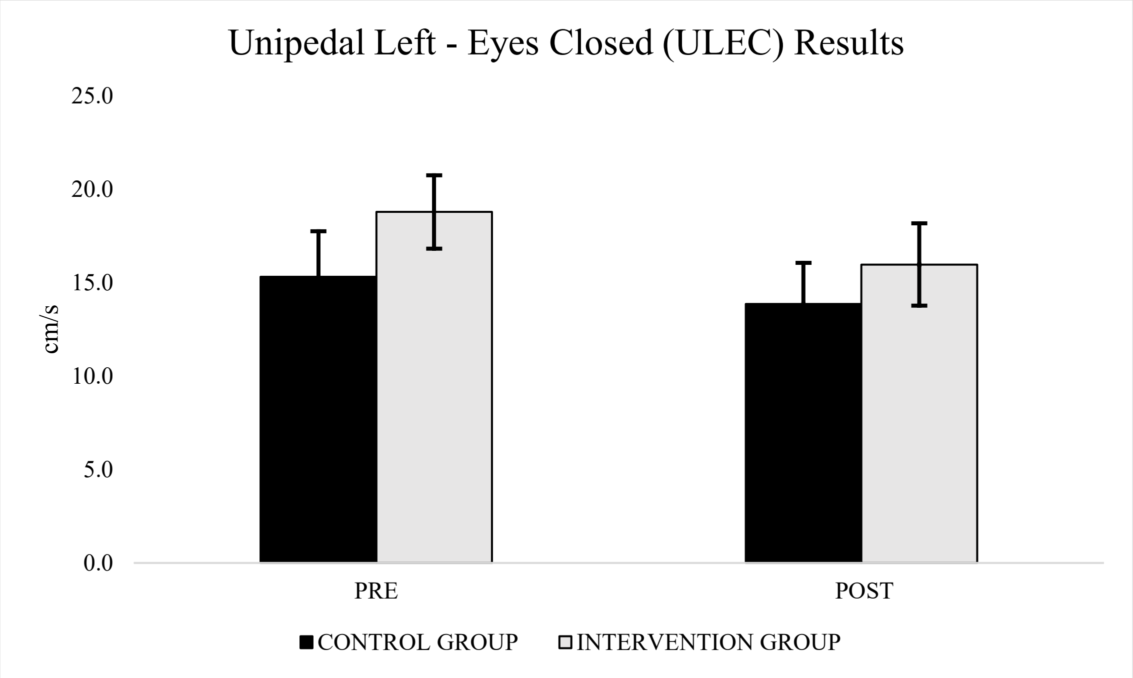

Figure 15: Unipedal Left - Eyes Closed (ULEC) Results, comparing average sway velocity (COPV) during the single leg left-side stance with eyes closed between the control and intervention group across the two-week training intervention.

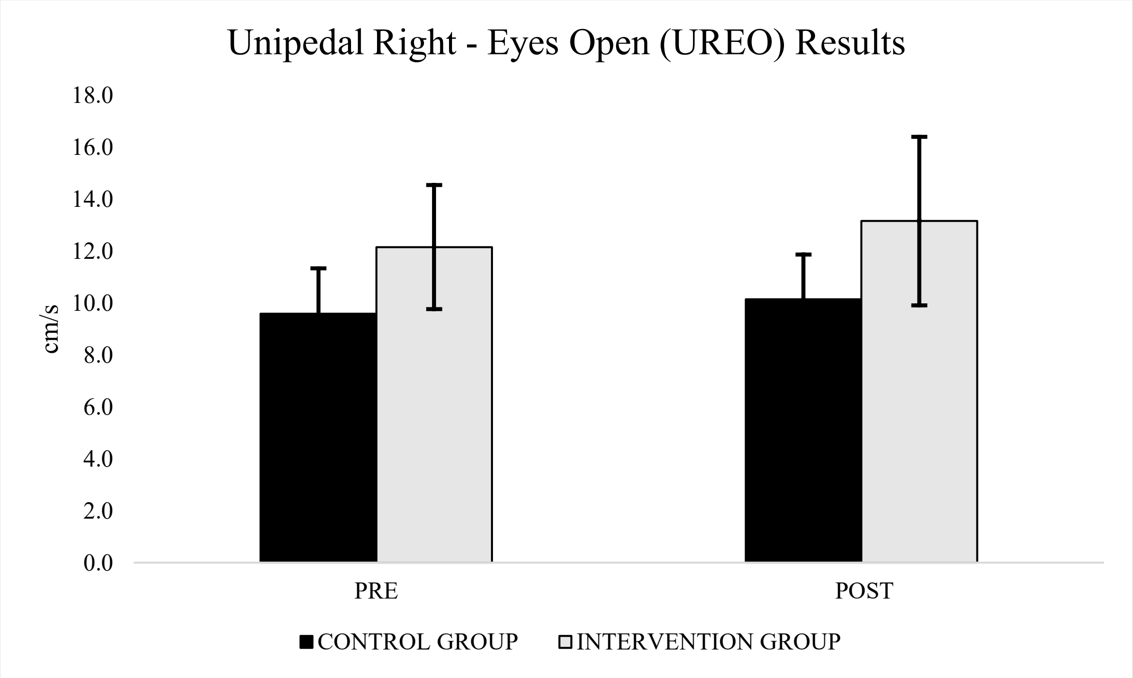

Figure 16: Unipedal Right - Eyes Open (UREO) Results, comparing average sway velocity (COPV) during the single leg right-side stance with eyes open between the control and intervention group across the two-week training intervention.

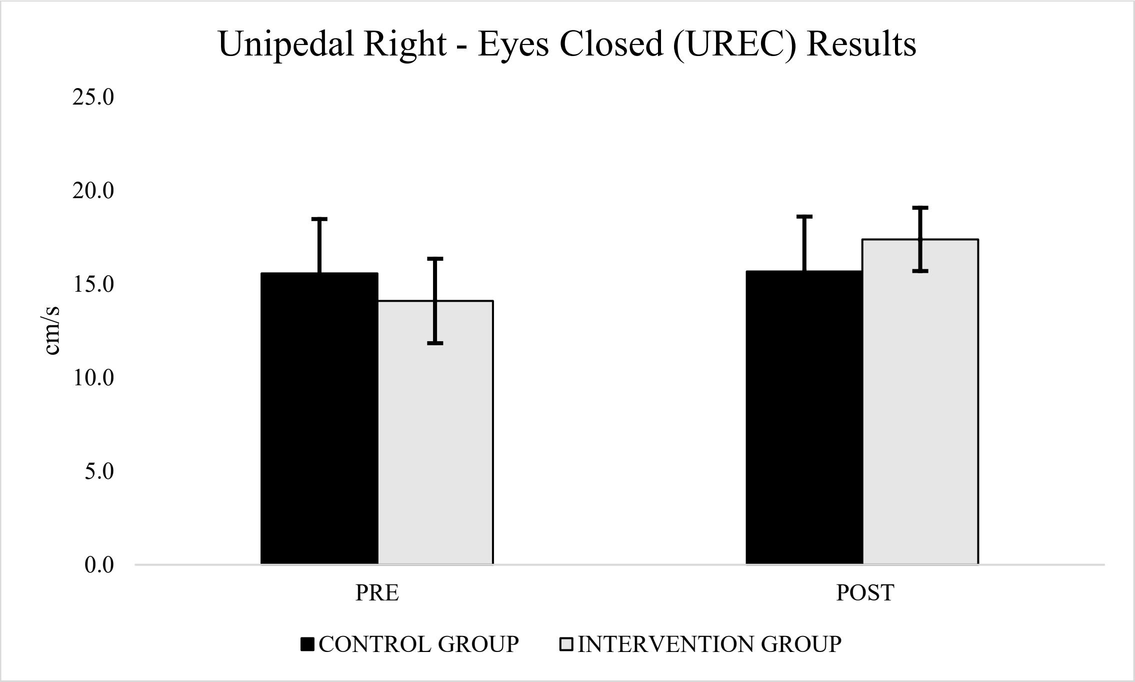

Figure 17: Unipedal Right - Eyes Closed (UREC) Results, comparing average sway velocity (COPV) during the single leg right-side stance with eyes closed between the control and intervention group across the two-week training intervention.

Table 4: Endurance and balance outcomes pre- and post-intervention. Results indicate group mean ± standard deviation.

	CONTROL				**INTERVENTION**			
Variable	Pre		Post		Pre		Post	
Endurance (s)								
CFET	53.2 ± 26.9		49.9 ± 25.9		53.0 ± 17.9		101.2 ± 43.8	
CEET	300.0 ± 0.0		286.8 ± 26.4		267.7 ± 33.8		296.2 ± 9.3	
COPV (cm/s)	EO	EC	EO	EC	EO	EC	EO	EC
Romberg	10.4 ± 12.4	6.2 ± 3.2	5.1 ± 4.1	10.0 ± 7.1	4.9 ± 2.0	5.1 ± 1.9	3.9 ± 2.3	4.3 ± 2.5
Modified Romberg	10.4 ± 8.4	11.1 ± 5.1	8.9 ± 5.1	8.1 ± 4.2	7.7 ± 3.1	10.9 ± 6.0	8.4 ± 3.7	7.6 ± 4.6
Single Leg Left	10.1 ± 4.7	15.3 ± 6.9	10.9 ± 5.6	13.9 ± 6.6	15.1 ± 8.1	18.8 ± 6.5	13.0 ± 8.8	16.0 ± 7.3
Single Leg Right	9.6 ± 5.2	15.6 ± 8.7	10.1 ± 5.2	15.7 ± 8.8	12.2 ± 7.9	14.1 ± 7.5	13.2 ± 10.8	17.4 ± 5.6

5. DISCUSSION

5.1. MAIN DISCUSSION

To the best of our knowledge, no other studies have investigated the use of a neck training program to influence balance performance. The hypotheses of this study were that 1) neck endurance would improve over a two-week intervention program, and that 2) improvements would be greater in flexion than extension, where finally 3) improvements in neck endurance in the intervention group would be related to an improvement in balance performance. The neck training intervention was intended to cause a short-term adaptation to fatigue resistance in the neck flexor and extensor muscles in the intervention group.

Although the intervention applied to the test group was only two weeks in duration, the results demonstrate significant improvements in neck flexor endurance, with time held almost doubling (90.9% increase). Both the intervention and control group flexor endurance averages at baseline were approximately 53 seconds, which is higher than other studies reporting normative endurance times of approximately 29 – 40 seconds in a similar age demographic (Domenech et al., 2011; Jarman et al., 2017). A study with a similar population showed averages of 32-36 seconds with a larger sample size, possibly with more variability than the population used in this study (Jarman et al., 2017). This presents an increase that would be considered clinically significant in populations with neck pain or disorders (Harris et al., 2005). The intervention used in this study took two weeks to complete, specifically selected to determine if a two-week time frame was sufficient to elicit improvements in neck endurance compared to studies that typically take at least 4-6 weeks to complete. It also utilized a simpler exercise program approach to minimize the time burden on participants and allow for easy replication (Chen et al., 2018; Peterson et al., 2015). This could have immediate practical applications for use in populations with neck dysfunction, as the improvement in neck endurance would possibly increase into and above normative ranges and reducing neck dysfunction (Borisut et al., 2006).

Typically, neuromuscular adaptations to training occur within the first several weeks of engaging in a training program, which could explain why such large changes occurred in a short period of time (Hanney & Kolber, 2007; Nezamuddin et al., 2013). Changes to the neck flexor group in this period of time may have been caused by improved efficiency to the contractile metabolism of sustained isometric contractions, where the muscles responsible for neck flexion developed an improved ability to resist fatigue at the muscular level (Gosselin et al., 2004). With the neck being responsible for neuromuscular in and outflow, yet being highly sensitive to fatigue, it is possible that the improvements to flexion endurance were so large because a novel training method was introduced to participants who had apparently untrained neck musculature (no direct neck endurance training intervention prior to study participation) and would possibly undergo a rapid adaptation (Strimpakos, 2011b; Vuillerme et al., 2005). During this time, it is likely that neuromuscular coordination improved, leading to more co-activation of the deep neck flexors, rather than defaulting to rely on the larger SCM (Rutherford & Jones, 1986; Sterling et al., 2001). This rapid and brief increase in flexion endurance could also be explained by the "learning effect" where a participant improves their skill through exposure to a given task, possibly through a central motor adaptation (Cannon & Cafarelli, 1987). Because participants had time to learn the requirements of the skill, they may have been able to learn from their experience and improve their performance leading to a pre-planned (central) or more efficient execution of the task. This is likely, as the method of exercise was novel to all participants and may have occurred in part alongside central and peripheral neuromuscular adaptations. Considering these possibilities, the first hypothesis was answered, and it appears that two weeks of isometric neck exercise is sufficient to elicit rapid changes in isometric neck endurance and possibly improve neck function, although the exact mechanism cannot be established (Gosselin & Fagan, 2014).

Changes in neck extension endurance were not significant, which may stem from the likelihood that extensor muscles at the neck require a greater stimulus to elicit a change than isometrically holding the head up, which is already the primary function of the neck extensors (Schomacher & Falla, 2013). In contrast to the neck flexor group, extension relies on the use of the superficial upper trapezius muscle to maintain a given head position. Thus, the test used may not have fatigued the trapezius enough to lead to further co-activation of deeper extensors (Johnson et al., 1994). This possible limitation, in conjunction with an artificial time ceiling placed on the extension test (5 minutes) may have curbed the ability to see a broader array of results by creating a ceiling effect. It is possible that either a longer test duration (no limit) or a more difficult test could lead to definitive results. Nevertheless, to address Hypothesis 2, we were able to show that neck flexor endurance improved to a larger degree than extension endurance, however this was possibly due to an unforeseen methodological limitation.

COPV ANOVA results showed few changes over the course of the study. The only sway velocity measurements with a significant change when comparing between groups in the post-intervention phase was the Romberg test with eyes closed (ROMEC). The reason for this testing condition presenting with changes is uncertain considering there were no other significant changes for other COPV measurements but may be caused by similar central learning mechanisms explained earlier that likely contributed to neck endurance improvements. The control group decreased in performance (faster COPV) creating a significant difference between the groups at post-test ($p = 0.031$), but there is no other interaction present. A neuromuscular adaptation to the balance condition through repeated exposure, or a learning effect could have occurred, where participants were able to actively improve their skill through conscious effort and learned experience gained from the baseline testing period, although they were explicitly told not to practice balance during their participation in the study (in both the control and intervention groups) (Balasubramaniam & Wing, 2002). These results appear to be anomalous in nature.

No relationship was found between neck endurance performance (in either flexion or endurance) and balance performance in the intervention group, diminishing the likelihood that neck endurance improvements in this study influenced balance performance. Currently there is an understanding that the neck plays a role in balance, but to what degree and what form of balance is still uncertain (Gosselin & Fagan, 2014). Our novel finding that the CFET correlates with the Romberg test supports the theory that neck flexor endurance may be a predictor of Romberg balance performance. The CEET, however, showed only negative correlations in the pre-intervention phase with pre-intervention ULEC, and post intervention ULEO and UREO. The cause for this is uncertain but suggests that there is no correlation between extensor endurance and single leg balance performance. It is possible that this is due to the way in which balance performance is controlled. When balancing on one leg, muscular coordination at the ankle and hip are recruited to maintain postural control, with the ankle being relied upon in simple balance tasks in the sagittal plane. Thus, suggesting that balance control occurred primarily around the lower extremity (Reimer & Wikstrom, 2010).These results seem to indicate that neck endurance may be a possible predictor of balance performance over a two week period rather than a controlling mechanism, but further research in this area would be necessary to substantiate this claim. In addressing Hypothesis 3, this study was unable to establish that improvements in neck endurance led to improvements in balance performance, as there was no significant change in balance.

5.2. LIMITATIONS

A major limitation the study was the choice of neck extension test, which appears to not have been sufficient to elicit meaningful changes in a two-week study period. In future, a more difficult test may be more appropriate to demonstrate significant changes in a short study period, such as the one defined by Ljungquist et al. where they utilized a loaded version of the CEET (Ljungquist et al., 1999). A further limitation could be the brief time frame of the study; although showing strong support for the use of short-term neck flexion training to elicit changes in flexion endurance, the timeframe may be too short to also observe changes in balance performance. There may have been central adaptations (learning) to balance which were not evident in such a short time. In future, a longer exercise intervention may be necessary to explore more definitive changes in balance control. These changes were formalized into a document for a proposed follow up study which addressed these limitations and would have possibly provided more definitive answers to the research question at hand. The proposed study, however, faced significant roadblocks, including the arrival of the COVID-19 pandemic which curbed the ability of the follow up study to occur.

5.3. CONCLUSION

In conclusion, we can resolve that neck flexor endurance can greatly improve in as little as two weeks, however extensor endurance may require a greater stimulus to elicit any adaptations. Secondly, neck endurance improvements appear not to be related to balance performance improvements but may serve as a predictor for balance performance in certain conditions based on other studies. In future, adjustments could be made to this study design in response to these results. A more difficult endurance test should be selected, and a longer study duration may be necessary to detect meaningful changes beyond the neuromuscular adaptation period.

5.4. FUTURE DIRECTIONS

This project could be expanded into a 6-week time frame, with three 2-week cycles that utilize more appropriate extension testing, and more concise balance testing. It is possible that fortifying neck musculature against fatigue may show a clearer interaction with balance performance when balance testing occurs both at rest and under neck fatigue; where an improvement in balance while the neck is fatigued may better indicate a peripheral adaptation has occurred rather than a central override. The neck appears to play a role in balance performance, but this is still not definitively understood. The proposed future study could subsequently lead to research in older adult populations to further manage fall prevention, in occupational settings involving neck pain, and in athletic settings dealing with pre- or post-concussion management. There is merit in exploring the effects of neck endurance on balance control by comparing visual conditions to a further degree, which could inform if there are adaptations occurring that show increased proprioceptive control in lieu of visual input. It is well understood that vision is a core component of balance control; a future study could observe the changes in balance without the use of vision, or under different levels of visual input (occluded or monocular). If balance control improves through neck endurance training despite the condition of visual input, it would be possible to infer that proprioceptive control is increasing independent of vision. This would have large implications for balance control in populations with visual deficits or impairments. A further look into comparisons between balance tests would also be necessary to determine if neck fatigue impacts balance control differently (ankle versus hip dominant balance), as it remains unclear as to which degree various modalities of balance testing are influenced by fatigue in the cervical musculature.

Additionally, there is merit in exploring different exercises modalities in future studies to elicit adaptations in neck muscles. These could include flexion and extension specific exercises, under progressive load rather than for increased time (looking at strength increased as they relate to balance). Literature has shown that heavy compound exercises have full-body effects could be utilized, however this is not definitive (Conley et al., 1997). The task-specific nature of training in the same position as a test ensures ease of execution, but other modalities of exercise should be looked at in future studies as their impacts may be valid and useful.

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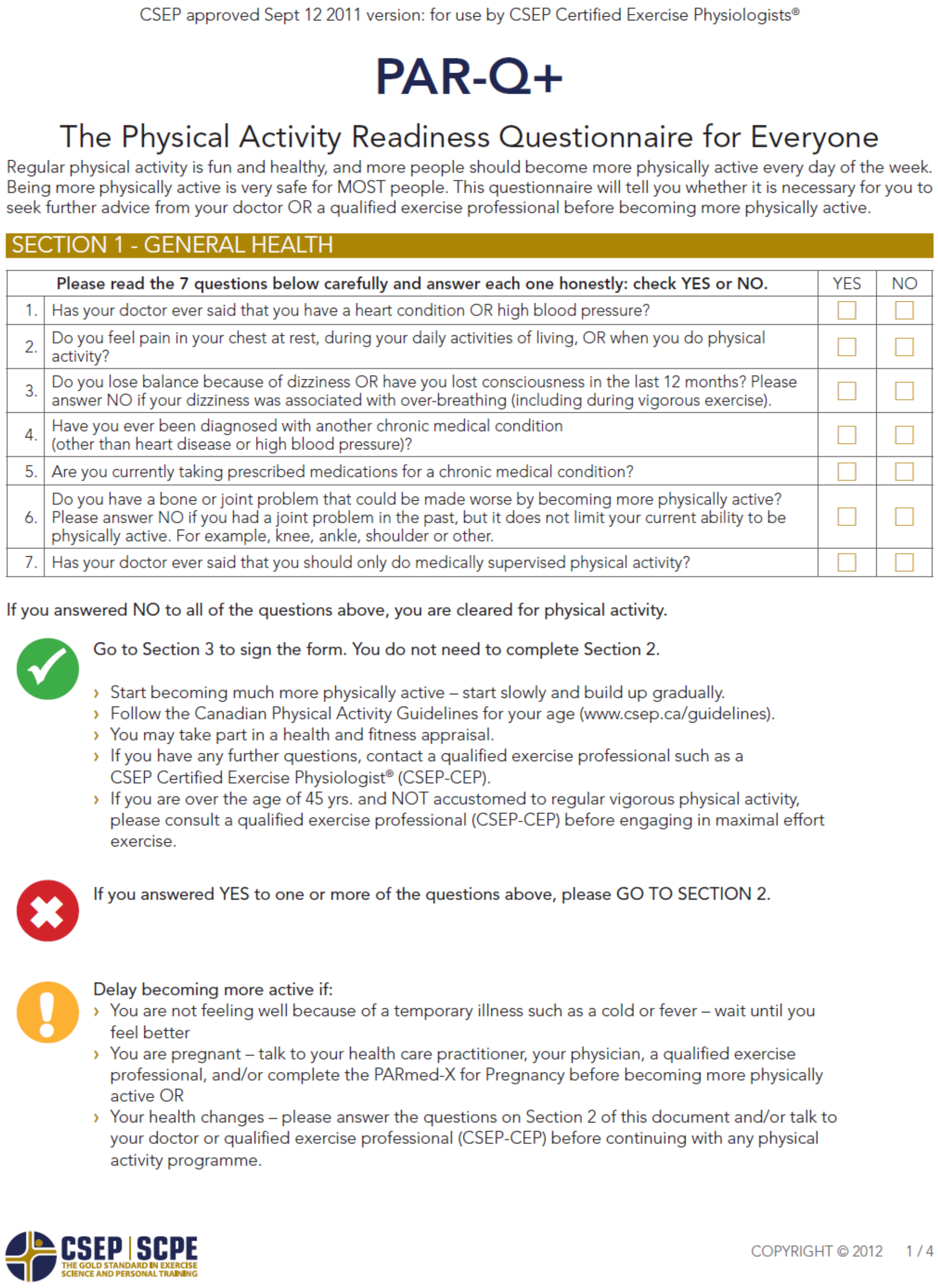
Appendix A PARQ+ Questionnaire



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PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

Regular physical activity is fun and healthy, and more people should become more physically active every day of the week. Being more physically active is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

SECTION 1 - GENERAL HEALTH

	Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1.	Has your doctor ever said that you have a heart condition OR high blood pressure?	☐	☐
2.	Do you feel pain in your chest at rest, during your daily activities of living, OR when you do physical activity?	☐	☐
3.	Do you lose balance because of dizziness OR have you lost consciousness in the last 12 months? Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4.	Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)?	☐	☐
5.	Are you currently taking prescribed medications for a chronic medical condition?	☐	☐
6.	Do you have a bone or joint problem that could be made worse by becoming more physically active? Please answer NO if you had a joint problem in the past, but it does not limit your current ability to be physically active. For example, knee, ankle, shoulder or other.	☐	☐
7.	Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.

✓ Go to Section 3 to sign the form. You do not need to complete Section 2.

- › Start becoming much more physically active – start slowly and build up gradually.
- › Follow the Canadian Physical Activity Guidelines for your age (www.csep.ca/guidelines).
- › You may take part in a health and fitness appraisal.
- › If you have any further questions, contact a qualified exercise professional such as a CSEP Certified Exercise Physiologist® (CSEP-CEP).
- › If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

✖ If you answered YES to one or more of the questions above, please GO TO SECTION 2.

! Delay becoming more active if:

- › You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better
- › You are pregnant – talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
- › Your health changes – please answer the questions on Section 2 of this document and/or talk to your doctor or qualified exercise professional (CSEP-CEP) before continuing with any physical activity programme.

1 / 4

SECTION 2 - CHRONIC MEDICAL CONDITIONS

	Please read the questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1.	Do you have Arthritis, Osteoporosis, or Back Problems?	☐ If yes, answer questions 1a-1c	☐ If no, go to question 2
1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	☐	☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	☐	☐
2.	Do you have Cancer of any kind?	☐ If yes, answer questions 2a-2b	☐ If no, go to question 3
2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?	☐	☐
2b.	Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?	☐	☐
3.	Do you have Heart Disease or Cardiovascular Disease? This includes Coronary Artery Disease, High Blood Pressure, Heart Failure, Diagnosed Abnormality of Heart Rhythm	☐ If yes, answer questions 3a-3e	☐ If no, go to question 4
3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g. atrial fibrillation, premature ventricular contraction)	☐	☐
3c.	Do you have chronic heart failure?	☐	☐
3d.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer YES if you do not know your resting blood pressure)	☐	☐
3e.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	☐	☐
4.	Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes	☐ If yes, answer questions 4a-4c	☐ If no, go to question 5
4a.	Is your blood sugar often above 13.0 mmol/L? (Answer YES if you are not sure)	☐	☐
4b.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, and the sensation in your toes and feet?	☐	☐
4c.	Do you have other metabolic conditions (such as thyroid disorders, pregnancy-related diabetes, chronic kidney disease, liver problems)?	☐	☐
5.	Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome)	☐ If yes, answer questions 5a-5b	☐ If no, go to question 6
5a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
5b.	Do you also have back problems affecting nerves or muscles?	☐	☐

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Please read the questions below carefully and answer each one honestly: check YES or NO.			YES	NO
6.		Do you have a Respiratory Disease? This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure	☐ If yes, answer questions 6a-6d	☐ If no, go to question 7
	6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	6b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	☐	☐
	6c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	☐	☐
	6d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	☐	☐
7.		Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia	☐ If yes, answer questions 7a-7c	☐ If no, go to question 8
	7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	7b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	☐	☐
	7c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	☐	☐
8.		Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event	☐ If yes, answer questions 8a-c	☐ If no, go to question 9
	8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	8b.	Do you have any impairment in walking or mobility?	☐	☐
	8c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	☐	☐
9.		Do you have any other medical condition not listed above or do you live with two chronic conditions?	☐ If yes, answer questions 9a-c	☐ If no, read the advice on page 4
	9a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months OR have you had a diagnosed concussion within the last 12 months?	☐	☐
	9b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	☐	☐
	9c.	Do you currently live with two chronic conditions?	☐	☐

Please proceed to Page 4 for recommendations for your current medical condition and sign this document.

PAR-Q+

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active:

- It is advised that you consult a qualified exercise professional (e.g., a CSEP-CEP) to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually – 20-60 min. of low- to moderate-intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate-intensity physical activity per week.
- If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

If you answered YES to one or more of the follow-up questions about your medical condition:

- You should seek further information from a licensed health care professional before becoming more physically active or engaging in a fitness appraisal.

Delay becoming more active if:

- You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise profesional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
- Your health changes - please talk to your doctor or qualified exercise professional (CSEP-CEP) before continuing with any physical activity programme.

SECTION 3 - DECLARATION

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The Canadian Society for Exercise Physiology, the PAR-Q+ Collaboration, and their agents assume no liability for persons who undertake physical activity. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.
- Please read and sign the declaration below:

> *I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that they maintain the privacy of the information and do not misuse or wrongfully disclose such information.*

NAME ______________________________ DATE ______________________

SIGNATURE ______________________ WITNESS ____________________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________________

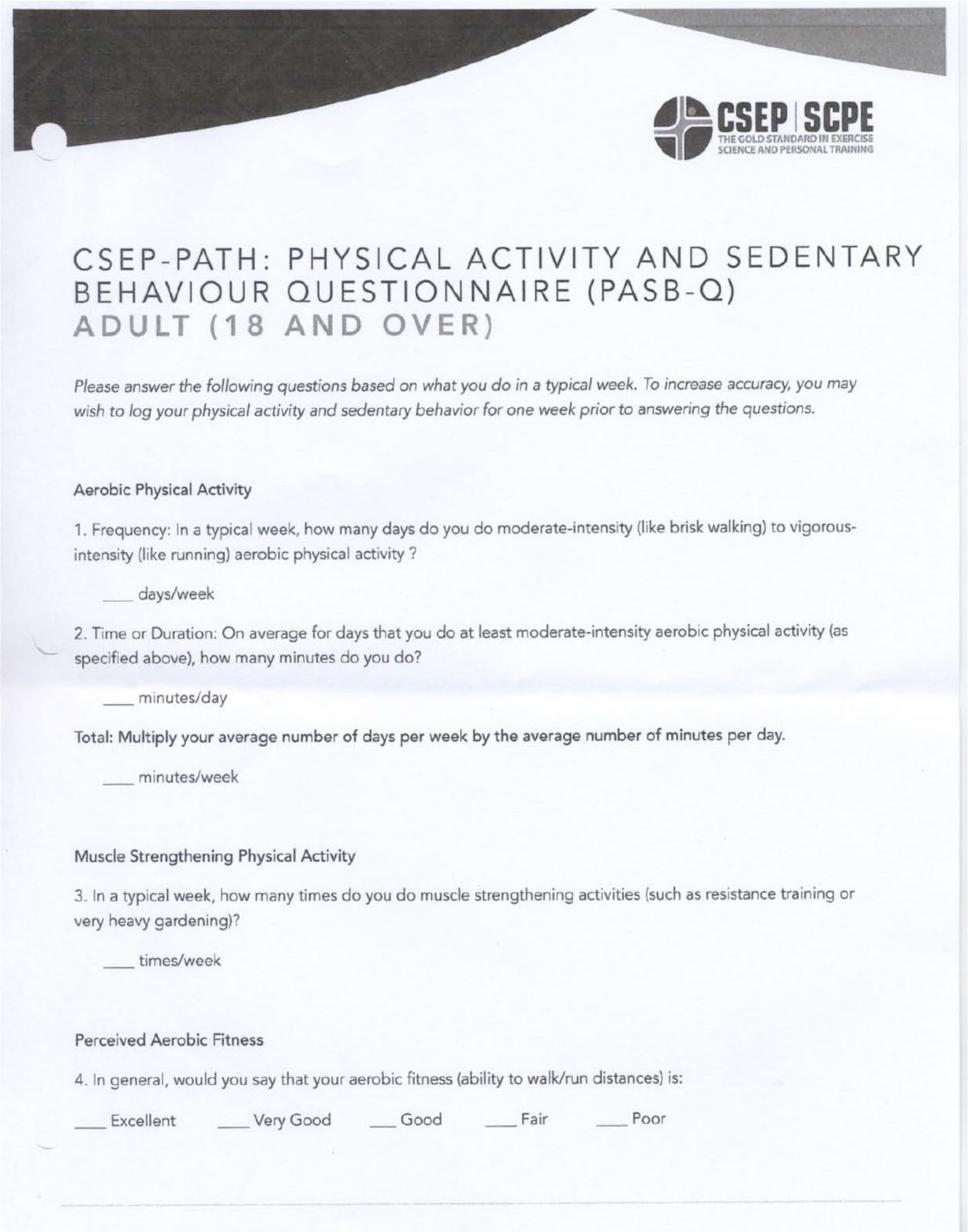
For more information, please contact:
Canadian Society for Exercise Physiology
www.csep.ca

KEY REFERENCES

1. Jamnik VJ, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the effectiveness of clearance for physical activity participation; background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or BC Ministry of Health Services.

Appendix B PASBQ Questionnaire



CSEP | SCPE
THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

CSEP-PATH: PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOUR QUESTIONNAIRE (PASB-Q)

ADULT (18 AND OVER)

Please answer the following questions based on what you do in a typical week. To increase accuracy, you may wish to log your physical activity and sedentary behavior for one week prior to answering the questions.

Aerobic Physical Activity

1. Frequency: In a typical week, how many days do you do moderate-intensity (like brisk walking) to vigorous-intensity (like running) aerobic physical activity ?

____ days/week

2. Time or Duration: On average for days that you do at least moderate-intensity aerobic physical activity (as specified above), how many minutes do you do?

____ minutes/day

Total: Multiply your average number of days per week by the average number of minutes per day.

____ minutes/week

Muscle Strengthening Physical Activity

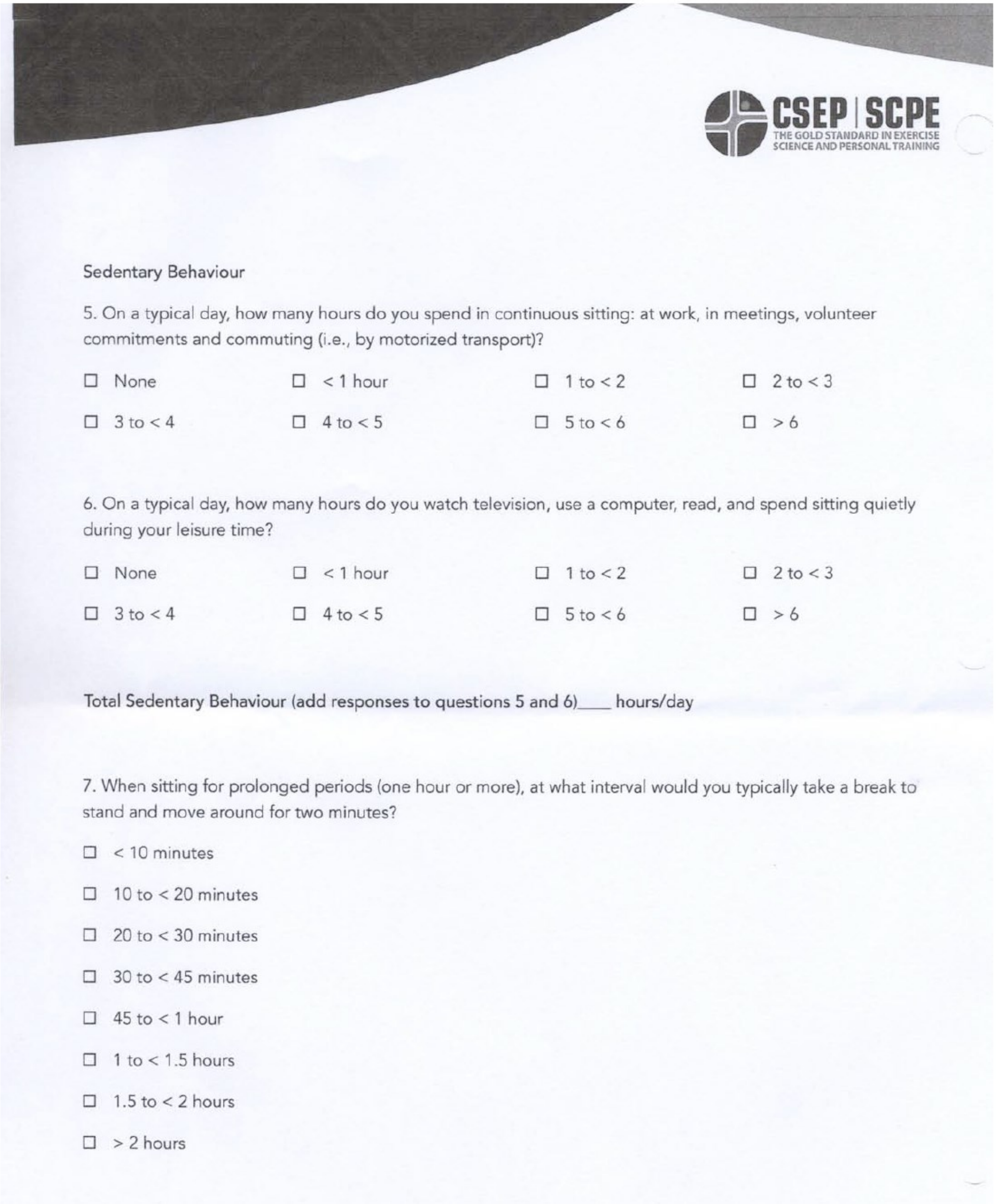
3. In a typical week, how many times do you do muscle strengthening activities (such as resistance training or very heavy gardening)?

____ times/week

Perceived Aerobic Fitness

4. In general, would you say that your aerobic fitness (ability to walk/run distances) is:

____ Excellent   ____ Very Good   ____ Good   ____ Fair   ____ Poor



CSEP | SCPE
THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

Sedentary Behaviour

5. On a typical day, how many hours do you spend in continuous sitting: at work, in meetings, volunteer commitments and commuting (i.e., by motorized transport)?

☐ None ☐ < 1 hour ☐ 1 to < 2 ☐ 2 to < 3

☐ 3 to < 4 ☐ 4 to < 5 ☐ 5 to < 6 ☐ > 6

6. On a typical day, how many hours do you watch television, use a computer, read, and spend sitting quietly during your leisure time?

☐ None ☐ < 1 hour ☐ 1 to < 2 ☐ 2 to < 3

☐ 3 to < 4 ☐ 4 to < 5 ☐ 5 to < 6 ☐ > 6

Total Sedentary Behaviour (add responses to questions 5 and 6)____ hours/day

7. When sitting for prolonged periods (one hour or more), at what interval would you typically take a break to stand and move around for two minutes?

☐ < 10 minutes

☐ 10 to < 20 minutes

☐ 20 to < 30 minutes

☐ 30 to < 45 minutes

☐ 45 to < 1 hour

☐ 1 to < 1.5 hours

☐ 1.5 to < 2 hours

☐ > 2 hours

Appendix C Screening Form

Screening Questionnaire

Study: The Effects of a 2-Week Isometric Neck Exercise Training Program on Standing Balance.

To be completed over the phone. The researcher will ask the following questions: no records will be kept. **This is not provided in paper to the prospective participant.**

If you answer yes to any of these questions, you will not be able to participate in the study. You do not need to disclose what you answered yes to, but please notify the researchers.

1. Have you ever had a concussion?
2. Have you ever had a significant neck injury?
3. Have you ever suffered nerve damage that led to limited motor function?
4. Do you have any visual limitations that are not corrected by a visual aid?
5. Have you ever had any musculoskeletal injuries that impair normal body function?
6. Have you had persistent neck pain in the past 3 months, and have you had persistent neck pain for longer than 3 months?
7. Have you ever had/have a balance disorder?
8. Do you have any other conditions that affect balance or neck function?

Appendix D Recruitment Flyer

WANT TO GET INVOLVED IN RESEARCH?

-VOLUNTEERS NEEDED-

Erik Richard is leading a research project looking at the effects of neck exercise on standing balance in the Kinesiology Department's Biomechanics lab. Participation requires between 2-4 hours over a 2-week period.

- *Are you an adult between the ages of 18 and 64?*
- *Are you curious about your balance capabilities?*
- *Do you like to exercise regularly?*
- *If you have had any conditions that adversely affect balance or cause neck pain in the last 6 months (i.e., concussion, spinal cord injury, etc.) you may not be able to participate in the study.*

If you answered yes to questions 1, 2, and 3, you may be eligible to participate in this study! Please contact Erik using the following information if you have any questions:

Phone: **902-494-2066**
Email: biodynamics.dalhousie@gmail.com

Balance Study / Richard 902-494-2066 biodynamics.dalhousie@ gmail.com	Balance Study / Richard 902-494-2066 biodynamics.dalhousie@ gmail.com	Balance Study / Richard 902-494-2066 biodynamics.dalhousie@ gmail.com	Balance Study / Richard 902-494-2066 biodynamics.dalhousie@ gmail.com	Balance Study / Richard 902-494-2066 biodynamics.dalhousie@ gmail.com	Balance Study / Richard 902-494-2066 biodynamics.dalhousie@ gmail.com	Balance Study / Richard 902-494-2066 biodynamics.dalhousie@ gmail.com	Balance Study / Richard 902-494-2066 biodynamics.dalhousie@ gmail.com	Balance Study / Richard 902-494-2066 biodynamics.dalhousie@ gmail.com	Balance Study / Richard 902-494-2066 biodynamics.dalhousie@ gmail.com	Balance Study / Richard 902-494-2066 biodynamics.dalhousie@ gmail.com	Balance Study / Richard 902-494-2066 biodynamics.dalhousie@ gmail.com	Balance Study / Richard 902-494-2066 biodynamics.dalhousie@ gmail.com

Appendix E(a) Email Communication Template

Good [appropriate time of day],

Thank you for expressing your interest in the study titled: **"The Effects of a 2-Week Isometric Neck Exercise Training Program on Standing Balance."**

To determine your ability to participate in the study, please call 902-494-2066 to speak with Erik Richard in the Biodynamics, Ergonomics and Neuroscience (BEN) lab. Erik will be able to answer any questions you may have about the study and ask you several important screening questions (none of which will be recorded).

If you pass the screening procedure, Erik will send you several forms to complete and bring to the initial meeting session. These will include an informed consent, physical activity readiness, and physical activity forms.

Should you have any questions about any of these forms you may contact this email at any time.

Thank you again for your interest, and we look forward to hearing from you soon!

Best,

Erik Richard

BEN lab Research Team

Appendix E(b) Phone Communication Template

Thank you for expressing your interest in the study titled: _**"The Effects of a 2-Week Isometric Neck Exercise Training Program on Standing Balance."**

Do you have any questions about the study?

[Should the participant be satisfied with all answers, move on to screening]

I am going to have to ask you a series of questions to ensure that you can participate in the study.

[Read from the screening questionnaire (Appendix G)]

<u>Option A</u>: Unfortunately, you will not be able to participate in the study. I would like to thank you for your interest, and I hope you enjoy the rest of your day! *[Should the prospective participant answer yes to one of the screening questions]*

<u>Option B</u>: Excellent, based on your answers we can move forward. I am going to email you some forms to complete, do you have a preferred email? These will include an informed consent, physical activity readiness, and physical activity forms.

Should you answer yes to any questions on the PARQ+ form, you may call and ask how to proceed. When would you be able to meet to begin your participation in the study?

[Set a time with the participant]

Thank you again for your interest, and we look forward to seeing from you soon!

Best,

Erik Richard

BEN lab Research Team

Appendix F Consent form

RESEARCH CONSENT FORM

- Introduction

We invite you to take part in a research project called ***<u>"The Effects of a 2-Week Isometric Neck Exercise Training Program on Standing Balance."</u>*** This study is being done by **Erik Richard** a master's student in the department of Kinesiology at Dalhousie University in Halifax, Nova Scotia. This research project is an independent study being led by Erik Richard as part of his master's degree Thesis. The project is being supervised by **Dr. Janice Moreside** of the Kinesiology faculty in the School of Health and Human Performance, within the Faculty of Health.

The information in this form describes our research project and outlines what will be asked of you. It also tells you about any benefits, inconveniences, or discomforts you may experience. You may take part in this study if you are between the age of 18-64, and currently do not possess any conditions that negatively affect balance. At least 16 people will be taking part in this research project alongside you. Screening questionnaires will be provided to you via email to assess your readiness to participate in physical activity and the study. Once your eligibility has been confirmed, you will be scheduled in to participate in the study procedures as a voluntary participant in the Biodynamics and Neuroscience Lab at Dalhousie University. You will be provided with copies of all paperwork that you complete during your time in the study.

- Testing
  This project aims to help us understand the effects of neck exercise on human standing balance. We will ask you to take part in a series of non-invasive tests four times over a 6-7-week period. **You will be randomly placed into the intervention or control group**. The testing procedure is broken down in the following sections:

<u>Time Requirement Breakdown</u>

- *All participants – consent & screening process (5-10 minutes)*
  - *Neck Training Intervention Group*
    - *Day 1 (neck endurance testing) = 30 minutes x 2 sessions (60 minutes total)*

    - *Day 2 (balance testing) = 45-60 minutes x 2 sessions (1.5-2 hours total)*
    - *Week 1 check-in = 10 minutes*
    - *Neck Program = 6 sessions = 1-2 minutes x 3 sessions per week (6-12 minutes total)*
    - *TOTAL TIME = 2-4 hours over 2-3 weeks*
- *Control Group*
    - *Same as intervention group testing expect no Week 1 check-in and neck program.*
    - *TOTAL TIME = 2-4 hours over 2-3 weeks.*
    - *No training program go about normal daily activities.*

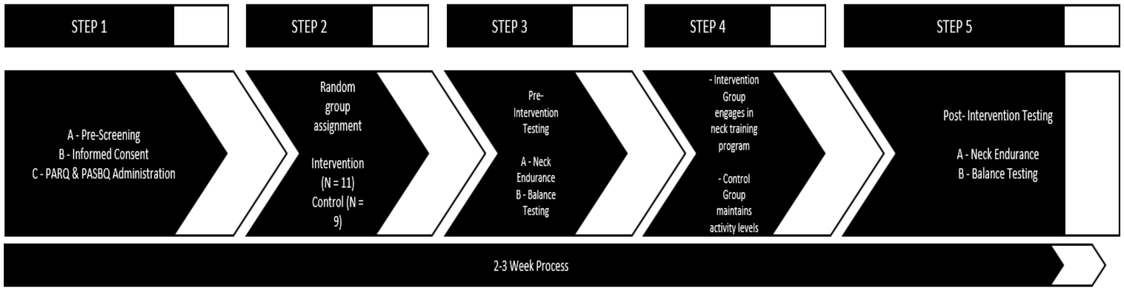


Figure 1: Schematic of Study Timeline

Testing Procedure

Height & Weight

Both will be measured using a manual scale and stadiometer from the Biomechanics lab.

Neck Girth & Length

Neck measurements (length and girth) will be manually taken using a tape measure. You will be measured for neck girth just above the Adam's apple (for men), or just below the jaw line (for women). Neck length (top of neck to the thoracic spine) will be measured in centimeters while seated upright. You will be asked if you are claustrophobic prior to girth measurements to avoid any potential discomfort during measurement.

This measurement information will be used to determine the relationship between neck characteristics and endurance as well as balance performance.

Cervical Neck Flexor Endurance Test

Neck flexion will be measured with you lying face-up on a treatment table (See the representation on Figure 2 below). You will adopt a chin-tuck position and slightly raise your head off the table, with the examiners hand just below the back of your head. When the test begins, you will be motivated with verbal encouragement to hold this position for as long as possible, without touching the examiner's hand. If you fail to stay off the examiners hand, or lose the chin-tucked position, the test is over. You will be given 2 practice trials of 10 seconds (with 30 seconds rest between each) to become familiar with the testing position. You will complete a maximum of 3 testing trials in addition to the two practice trials. For each trial, we will record how long you hold the chin-tuck position.

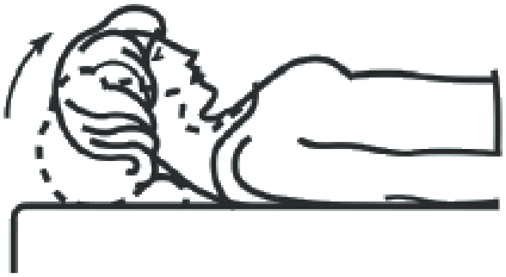


Figure 2: Craniocervical Flexion Endurance Test ("Neck Strengthening Exercises - Illustrated Rehab for Relief & Restoration," n.d.)

Cervical Extensor Endurance Test

The neck extensor test will require you to lie face down on a treatment table with your arms by your sides (see the example in figure 3 below). You will hold your head horizontally off the table in a neutral position. You will then receive the same practice trial guidelines as the flexion test.

When the test begins, you will be motivated with verbal encouragement to hold your head in a neutral (horizontal) position for as long as possible. During the test, If the change in horizontal position changes, or you drop your head completely, the test is done. Trials will be measured for time in seconds.

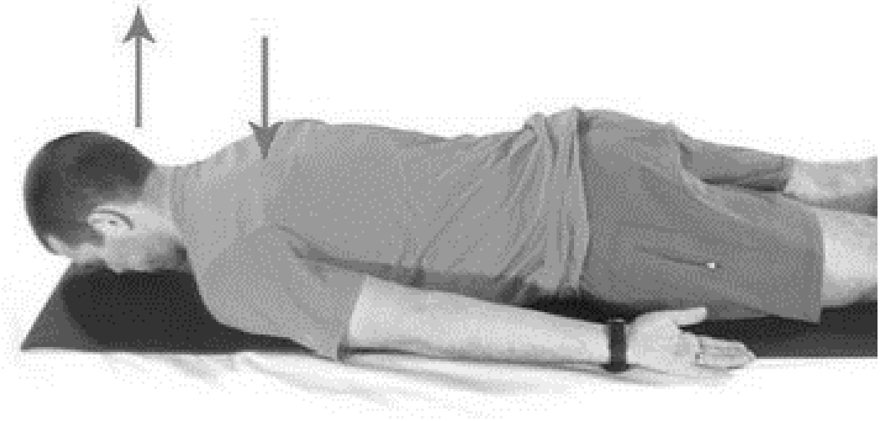


Figure 3: Cervical Extension Endurance Test (as seen in Shahidi, Johnson, Curran-Everett, & Maluf, 2012)

Balance Tests

Balance will be measured using a force measuring device called a force plate to evaluate how you balance by measuring the changes in pressure as you shift on your feet. The Modified Romberg test requires you to cross your arms over your chest and you will be given a visual target at eye level to look at when your eyes are open, to help prevent an undue fall or loss of balance. The test also asks for you to position one foot in front of the other (with your dominant foot forward) heel-to-toe with the back foot.

You will be instructed on how to perform each balance position and be given time to familiarize yourself with the stances. You will complete three eyes-open, and eyes-closed trials for the Romberg, Modified Romberg, and unipedal stance (left and right) tests. All balance tests will take 45-60 seconds, or restart if you lose balance (falling or a significant break in upright posture). A breakdown of the testing procedure can be seen in the table at the end of this section. You will go through balance testing in random order (eyes open or closed may be swapped).

Table 1: Testing Procedures Outline

Day 1 – Screening	Fill out necessary forms (PARQ, PASBQ) – This is only done the very first time.
Day 1 – Anthropometrics	Height, weight, neck length & girth

Day 1 – Neck Flexion & Extension Tests	CEET (cervical extension endurance test) & CFET (cervical flexion endurance test) as described above
Day 1 – Balance Baseline	Modified Romberg balance on force plate: 20s Eyes open / 20s Eyes closed depending on counterbalance assignment.
Day 2 – Post-Intervention Testing	Repeat all testing

Neck Training Program

For those randomly placed into the intervention group, the training will include 6 sessions over 2 weeks (See Table below), occurring 3 days per week (day completed is subject to change based on individual time constraints).

Training will require you to hold the chin-tucked position (flexion) while lying on your back (supine lying) and then hold the neck/head in a neutral position off the end of the plinth while lying on your stomach (prone lying).

The duration of hold time will progressively increase throughout the program. You will hold the designated positions for as long as indicated, switching between the two positions until all repetitions and sets are completed. If asked how difficult the neck exercises are, we are aiming for it to be approximately a 6 to 8 out of 10 (10 being maximal exertion).

No external implements will be required, and the exercises can be done while lying on the floor, or on a gym bench (solid surface preferred). You will not *need* access to a gym to complete this exercise program.

Those of you who will randomly be placed into the control group will be asked to continue your normal daily routines while avoiding exercises explicitly chosen to improve balance (balance exercises like the one outlined in testing for this study) and neck endurance (like the ones outlined in testing and training for this study.

- Participation Time Requirement

You will be randomly placed into an intervention or control group. The test group will be required to follow a neck specific exercise program for 2 weeks, while the control group will be asked to refrain from any specific neck or balance exercise.

- Training Effects: Risks and Benefits

This project aims to determine the effect of neck endurance training on standing balance. Participation in this study comes with minimal risk to your health, but you may experience feelings of local neck fatigue or weakness for a short period following neck endurance testing or the neck exercises in the intervention program. This is to be expected as exercise training targeting muscles often results in short term weakness followed by feelings of increased strength 2 or more days after training. To limit the risk of any unnecessary fatigue, you will be given adequate rest between tests and between trials within each test. The intervention program will also have built-in resting periods. The selection of isometric (static) exercises means that the chance of neck strain is minimal as you will be put into a stable position for all exercises. There are several benefits associated with engaging in the neck exercise program should you be placed in the test group. You may find that your neck feels more stable, and you may experience a reduction in neck fatigue. Following completion of the study, the neck exercise program will be available to all upon request for future use.

- Consent, Compensation & Privacy

It is your decision whether you want to take part in this research project. Even if you do take part, you can leave the study at any time for any reason. There will be no negative consequences for terminating participation in this study. If you decide to end your participation in the project, your data will be permanently removed. No compensation will be provided for participating in this research study.

All information you give to members of our research team will be kept private. When we share our project findings in papers or at presentations or conferences, we will only talk about group results and remove any chance to associate your name with any of the data. This means that it will not be possible for you to be identified. Any identifying information about you (like your name) will be kept in a separate location, away from the experimental results.

If you agree to participate in this research project, please sign this form and return it to the research team in person. We are happy to share our results with you after the data analysis has been complete, within 4-6 weeks of the end of the project. Should you have any further questions, please feel free to contact the research team before signing this form. Remember that signing this form does not absolve the researchers of their ethical responsibilities. Should you feel like the researchers are acting in an unethical or irresponsible manner, please do not hesitate to contact the Dalhousie Research Ethics Board.

I have read the explanation about this study. I understand what I am being asked to do and my questions about the study have been answered. I agree to take part in this study. I know that participating is my choice and that I can leave the study at any time.

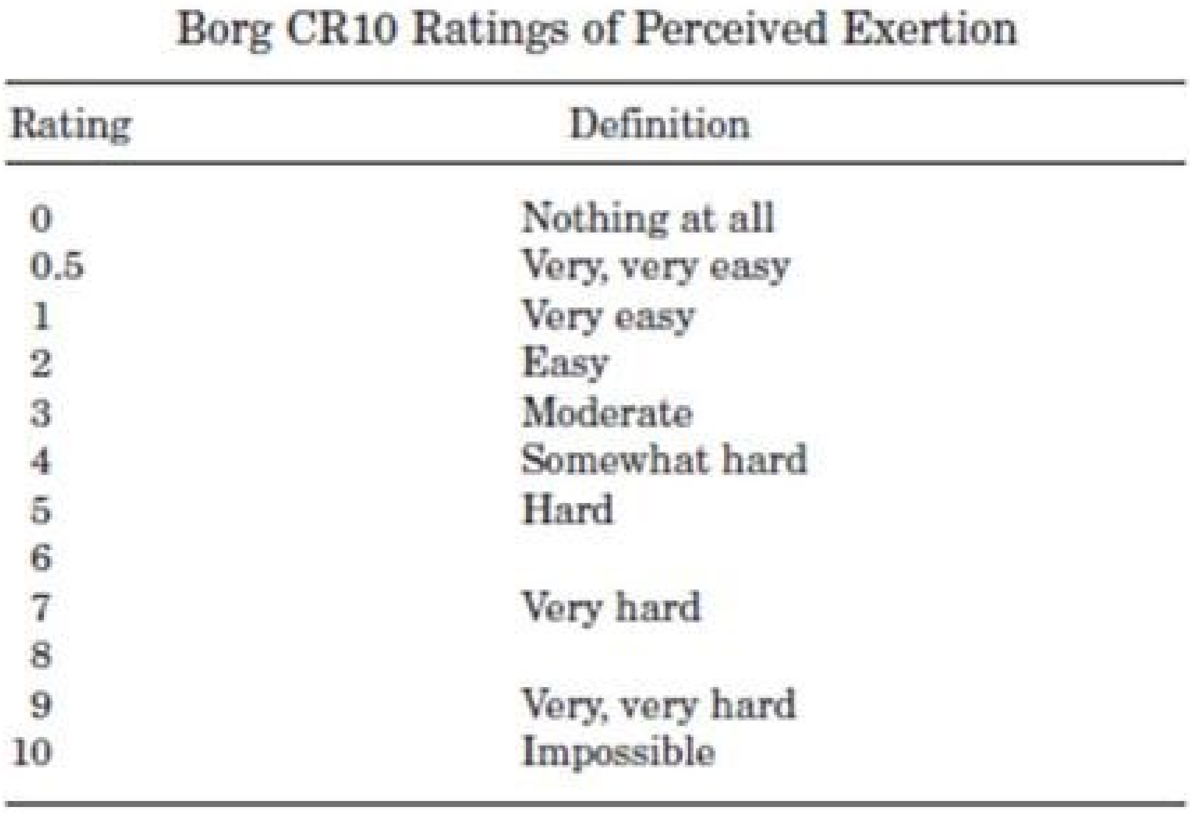
PARTICIPANT'S SIGNATURE	DATE

RESEARCHER'S SIGNATURE DATE

If you have any questions, comments, or concerns about your participation in this research project, please contact me, Erik Richard at, **902-494-2066** or RichardE@dal.ca. You can also contact my supervisor Dr. Janice Moreside, faculty member at the department of Kinesiology at JMoreside@dal.ca.

Should you have any concerns about this study and wish to contact the Dalhousie Research Ethics Board, please contact **902-494-3423**, or email them at ethics@dal.ca.

Appendix G BORG Scale - RPE Chart

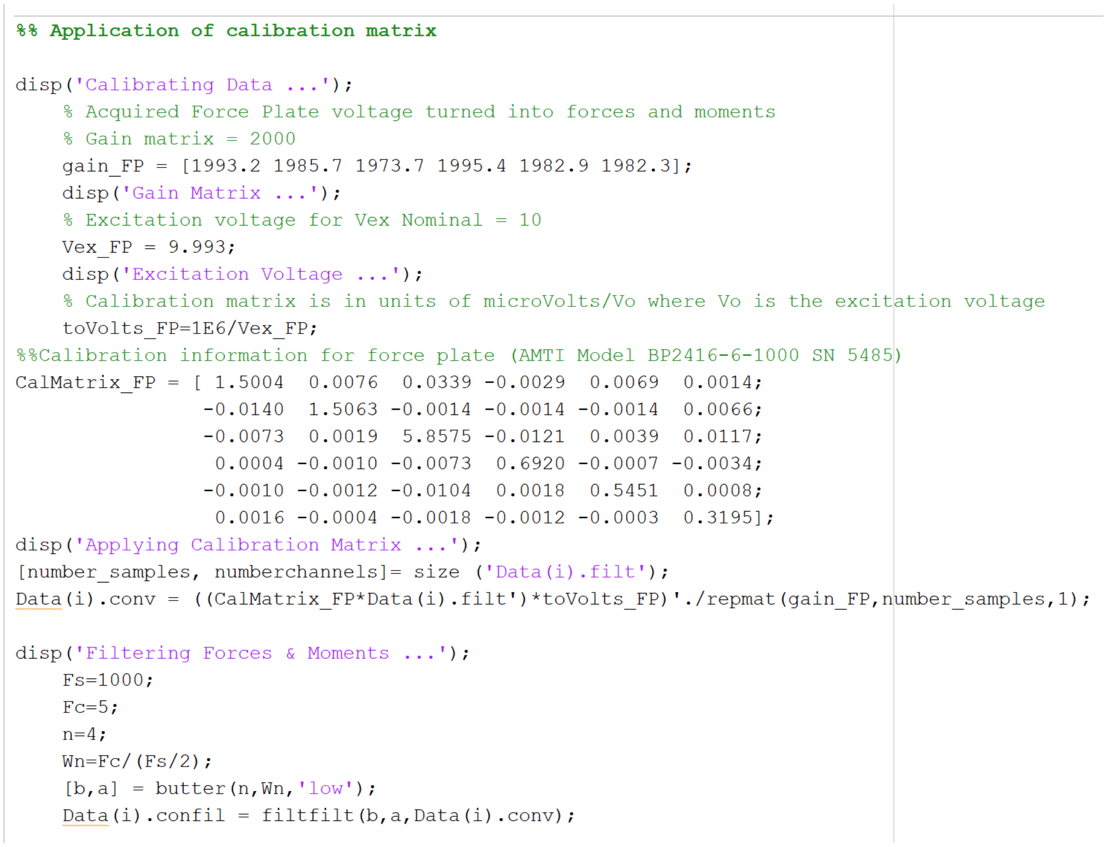


Borg CR10 Ratings of Perceived Exertion

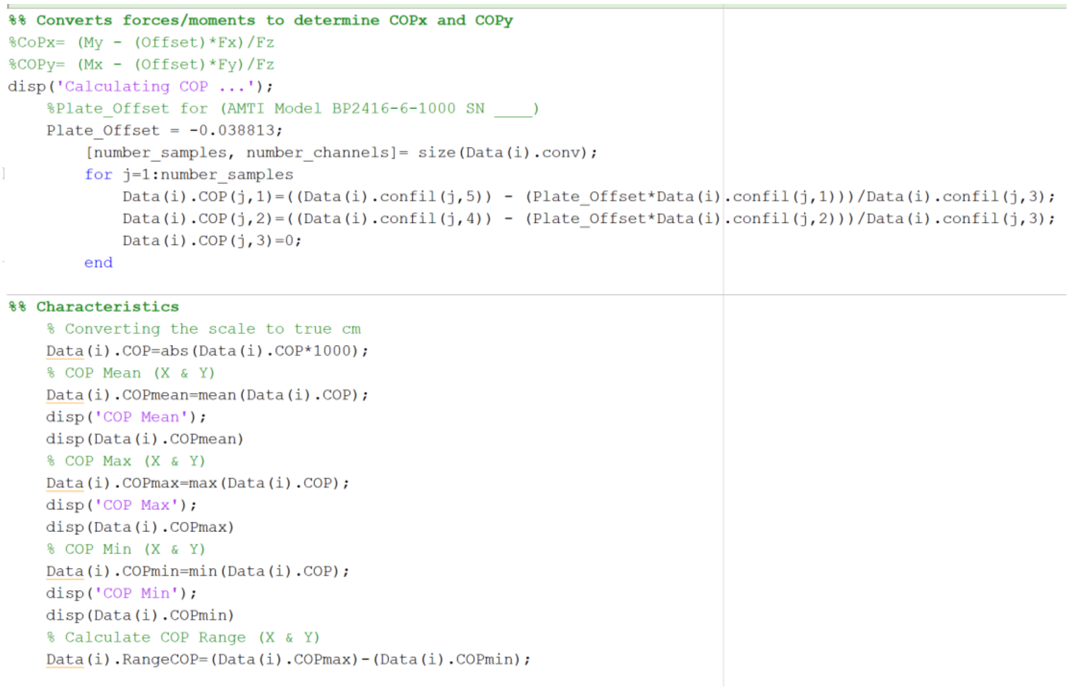
Rating	Definition
0	Nothing at all
0.5	Very, very easy
1	Very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	
7	Very hard
8	
9	Very, very hard
10	Impossible

Appendix H MatLab Code for Acquisition & Processing

```
%% Converting raw files to matrixes only
% Cuts Trials to channel 0-5 (FXYZ, MXYZ)

for i=1:2
    load(['Trial_' num2str(i) '.mat']);
    dath001=dath001(:,1:6);
    save(['Trial_' num2str(i) '.mat']);
end

clear;
clc;

%% Choose Number of Trials to Run
prompt = 'How many trials would you like to run? ';x = input(prompt);N = x;

for i=1:N
    load(['Trial_' num2str(i) '.mat']);
    Data(i).RAW=dath001;

%% Filtering
disp('Filtering RAW...');
    Fs=1000;
    Fc=5;
    n=4;
    Wn=Fc/(Fs/2);
    [b,a] = butter(n,Wn,'low');
    Data(i).filt = filtfilt(b,a,dath001);
% Saves filtered data into structured array
```



```
%% Application of calibration matrix

disp('Calibrating Data ...');
    % Acquired Force Plate voltage turned into forces and moments
    % Gain matrix = 2000
    gain_FP = [1993.2 1985.7 1973.7 1995.4 1982.9 1982.3];
    disp('Gain Matrix ...');
    % Excitation voltage for Vex Nominal = 10
    Vex_FP = 9.993;
    disp('Excitation Voltage ...');
    % Calibration matrix is in units of microVolts/Vo where Vo is the excitation voltage
    toVolts_FP=1E6/Vex_FP;
%%Calibration information for force plate (AMTI Model BP2416-6-1000 SN 5485)
CalMatrix_FP = [ 1.5004  0.0076  0.0339 -0.0029  0.0069  0.0014;
                -0.0140  1.5063 -0.0014 -0.0014 -0.0014  0.0066;
                -0.0073  0.0019  5.8575 -0.0121  0.0039  0.0117;
                 0.0004 -0.0010 -0.0073  0.6920 -0.0007 -0.0034;
                -0.0010 -0.0012 -0.0104  0.0018  0.5451  0.0008;
                 0.0016 -0.0004 -0.0018 -0.0012 -0.0003  0.3195];
disp('Applying Calibration Matrix ...');
[number_samples, numberchannels]= size ('Data(i).filt');
Data(i).conv = ((CalMatrix_FP*Data(i).filt')*toVolts_FP)'./repmat(gain_FP,number_samples,1);

disp('Filtering Forces & Moments ...');
    Fs=1000;
    Fc=5;
    n=4;
    Wn=Fc/(Fs/2);
    [b,a] = butter(n,Wn,'low');
    Data(i).confil = filtfilt(b,a,Data(i).conv);
```



```
%% Converts forces/moments to determine COPx and COPy
%CoPx= (My - (Offset)*Fx)/Fz
%COPy= (Mx - (Offset)*Fy)/Fz
disp('Calculating COP ...');
    %Plate_Offset for (AMTI Model BP2416-6-1000 SN ____)
    Plate_Offset = -0.038813;
        [number_samples, number_channels]= size(Data(i).conv);
        for j=1:number_samples
            Data(i).COP(j,1)=((Data(i).confil(j,5)) - (Plate_Offset*Data(i).confil(j,1)))/Data(i).confil(j,3);
            Data(i).COP(j,2)=((Data(i).confil(j,4)) - (Plate_Offset*Data(i).confil(j,2)))/Data(i).confil(j,3);
            Data(i).COP(j,3)=0;
        end

%% Characteristics
    % Converting the scale to true cm
    Data(i).COP=abs(Data(i).COP*1000);
    % COP Mean (X & Y)
    Data(i).COPmean=mean(Data(i).COP);
    disp('COP Mean');
    disp(Data(i).COPmean)
    % COP Max (X & Y)
    Data(i).COPmax=max(Data(i).COP);
    disp('COP Max');
    disp(Data(i).COPmax)
    % COP Min (X & Y)
    Data(i).COPmin=min(Data(i).COP);
    disp('COP Min');
    disp(Data(i).COPmin)
    % Calculate COP Range (X & Y)
    Data(i).RangeCOP=(Data(i).COPmax)-(Data(i).COPmin);
```

```
%% Visualization
figure
    hold all
    plot(Data(i).COP(:,1),Data(i).COP(:,2));
    title(['Trial(' num2str(i) ')']);
        xlabel('Anterior/Posterior Sway (cm)');
        ylabel('Medial/Lateral Sway (cm)');
%           Direction of participants changed to 90 degrees CCW

savefig(['Trial(' num2str(i) ')'])
% Changes file name
%%  Center of Pressure Velocity
        for l=1:number_samples
            Data(i).COPV(l,1)=Data(i).COP(sqrt(l-(l-1))/(1/Fs));
        end
        disp('COP Velocity');
        disp(Data(i).COPV)

save('Data')

end

clear
clc
```