Comparison of Cardiorespiratory Responses between Pool Floor and Overground Walking in People Post-Stroke

A thesis submitted in partial fulfillment of the requirements
For the degree of Master of Science in Kinesiology

By
Brenda Jeng

May 2016
The thesis of Brenda Jeng is approved:

____________________________________________________________________________________
Mai Narasaki-Jara, Doctoral Candidate                                        Date

____________________________________________________________________________________
Dr. Konstantinos Vrongistinos, PhD                                              Date

____________________________________________________________________________________
Dr. Teri Todd, PhD                                                              Date

____________________________________________________________________________________
Dr. Taeyou Jung, PhD, Chair                                                     Date

California State University, Northridge
Dedication

To my parents, John and Teresa
Acknowledgements

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Abstract

Comparison of Cardiorespiratory Responses between Pool Floor and Overground Walking in People Post-Stroke

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BACKGROUND: The energy cost of hemiparetic gait may limit performance of activities of daily living and physical activity of people post-stroke. Pool floor walking can provide a feasible and supportive method of exercise to improve cardiorespiratory endurance and walking ability of people post-stroke. The purpose of this study is to examine differences in cardiorespiratory responses to pool floor walking (PFW) and overground walking (OW).

METHODS: 14 people post-stroke (aged 58.00±15.51) and 14 healthy adults (age- and gender-matched) participated in this cross-sectional study. Participants performed both PFW and OW for six minutes of PFW at a matched speed. To match speed, lap times and cadence were used. Cardiorespiratory variables including energy expenditure (EE), oxygen consumption (VO\textsubscript{2}), and minute ventilation (V\textsubscript{E}) were collected using a telemetric metabolic system during rest and walking sessions.

RESULTS: People post-stroke did not show significant differences in cardiorespiratory responses between PFW and OW. However, healthy controls demonstrated significant increases in mean VO\textsubscript{2} values by 80\% (from 8.03±1.78 to 14.44±4.10, \textit{p}<0.00), mean EE values by 98\% (from 2.71±0.92 to 5.35±2.03, \textit{p}<0.00), and mean V\textsubscript{E} values by 67\%
(from 16.43±5.63 to 27.41±10.12, \( p<0.00 \)) while performing PFW when compared to OW. A significant group x condition interaction was found in VO\(_2\) (\( p<0.01, d=1.94 \)). The control group increased VO\(_2\) between the two walking conditions while the post-stroke group did not.

CONCLUSION: Our results suggest that walking in water does not require greater energy expenditure in people post-stroke whereas it does in healthy adults. The increased energy expenditure while walking in water appears to be associated with faster walking speed. The findings suggest that individuals post-stroke who cannot withstand long durations of gait training on land may practice gait training in water.
Introduction

Stroke is the leading cause of disability in the United States with approximately 795,000 new cases reported each year. Hemiparetic gait, a common motor deficit associated with stroke, limits functional mobility and contributes to excessive energy expenditure during walking (Detrembleur, Dierick, Stoquart, Chantraine, & Lejeune, 2003). Previous studies have reported hemiparetic gait to require twice the energy cost compared to that of the general population (Danielsson, Willén, & Sunnerhagen, 2007; Platts, Rafferty, & Paul, 2006). This elevated energy demand of hemiparetic gait is an indicator of compromised aerobic capacity, which contributes to reduced mobility. Early gait speed rehabilitation has been shown to increase mobility and to be associated with increased community participation in people post-stroke (van de Port, Kwakkel, & Lindeman, 2008). However, the high energy cost of hemiparetic gait may hinder people post-stroke from participating in physical activity, thus lowering their aerobic capacity. Therefore, it is critical to develop a mode of exercise to accommodate people post-stroke with hemiparesis who have elevated energy demands.

Cardiovascular fitness is essential to stroke rehabilitation. Aerobic capacity in individuals post-stroke, measured by peak oxygen consumption, ($VO_2$peak), has been found to be as low as 50-70% of that reported in age- and gender-matched sedentary individuals (Mackay-Lyons & Makrides, 2004). Poor cardiovascular fitness of individuals post-stroke results in reduced mobility due to an elevated energy demand during walking. This contributes to functional limitations and physical inactivity (Ivey, Hafer-Macko, & Macko, 2006; Paolucci et al., 2000). Due to physical inactivity, low aerobic fitness may increase the risk for secondary complications such as cardiovascular...
disease and type-II diabetes (Hamilton, Hamilton, & Zderic, 2007). Compromised aerobic capacity has also been shown to increase the risk of a subsequent stroke in people post-stroke who are physically inactive (Kurl et al., 2003).

Gait rehabilitation is one of the critical components in stroke recovery. Treadmill walking has become widely accepted as a method of gait rehabilitation in people post-stroke that has been shown to improve gait parameters such as gait speed (Tyrell, Roos, Rudolph, & Reisman, 2011). However, walking on a treadmill has been shown to expend more energy than walking overground (Brouwer, Parvataneni, & Olney, 2009), which may be challenging for people post-stroke in the early stages of stroke rehabilitation. In addition, Jung et al. (2013) found that aquatic treadmill walking resulted in lower energy expenditure than overground treadmill walking at a matched intensity.

Aquatic treadmill walking has been reported to lower the elevated energy demands of hemiparetic gait in individuals post-stroke. However, aquatic treadmills are not readily available or cost-effective, and while pool floor walking may be an optimal alternative to aquatic treadmill walking, the energy expenditure of this form of aquatic walking have not yet been elucidated. Pool floor walking (PFW) may provide individuals post-stroke with a feasible and effective mode of exercise to increase cardiorespiratory fitness without expending excessive energy. However, limited studies have examined the energy expenditure of pool floor walking in people post-stroke. Therefore, the purpose of this study is to compare cardiorespiratory responses between pool floor and overground walking in people post-stroke. It was hypothesized that cardiorespiratory responses to pool floor walking will be lower compared to that of overground walking in individuals post-stroke.
Literature Review

Definition and Incidence of Stroke

Stroke is defined as an interruption of blood flow to the brain (American Heart Association, 2015). This event may result in death of brain tissue due to the deprivation of oxygen and nutrients. While it is the fifth leading cause of death, stroke is also the leading cause of long-term disability in the U.S. Each year, approximately 795,000 people have a new or recurrent stroke, and about 185,000 of these cases are recurrent strokes. Every four minutes a person dies as a result of stroke.

Several factors increase the risk of stroke including smoking, alcohol consumption, physical inactivity, diabetes, high cholesterol and hypertension (American Heart Association, 2015). Out of all risk factors, hypertension is the most critical predictor of ischemic stroke, and individuals with hypertension have the greatest risk (Ohira et al., 2006). Male adults with higher cardiovascular fitness, expressed as maximal oxygen consumption (VO$_2$max), have lower risk of onset of stroke (Kurl et al., 2003). Therefore, improving cardiovascular fitness is critical to decrease the risk of stroke in healthy adults and recurrent stroke in individuals post-stroke and to prevent any secondary conditions, such as cardiovascular disease.

Classifications of Stroke

The two main types of strokes are ischemic and hemorrhagic ("Center for Disease Control and Prevention: Types of Stroke," 2015). An ischemic stroke occurs when a blood clot blocks a vessel of the brain, interrupting blood flow, whereas a hemorrhagic stroke is defined as a rupture of a weakened artery in the brain that results in bleeding into the surrounding area of or into the brain (American Heart Association, 2015).
Approximately 87% of the all stroke cases are ischemic, and 13% are hemorrhagic (American Heart Association, 2015). Thrombosis and embolism are the two main kinds of ischemic stroke. A thrombotic stroke is caused when the development of a blood clot attached to the wall of an artery interrupts blood flow within the brain. A cerebral embolism occurs when a blood clot, developed from the arterial walls located outside the brain, travels through the circulatory system and becomes lodged into an artery of the brain too small to pass through. A third type of ischemic stroke is a transient ischemic attack (TIA), often called “mini-stroke.” It is caused by a temporary clot, causing symptoms that usually last less than five minutes. A person does not experience permanent damage to brain tissue following a TIA. However, a TIA is a high indicator of the onset of a second stroke, giving a person time to prevent a second and more serious stroke to occur. Approximately a third of people who have TIA have a second stroke within the year.

Two types of hemorrhagic stroke include intracerebral and subarachnoid hemorrhage. Intracerebral hemorrhage, the most common type of hemorrhagic stroke, occurs when a blood vessel bursts within the brain. Subarachnoid hemorrhage refers to when the ruptured vessel bleeds into the subarachnoid space, or the area between the brain and the tissues covering the brain. This kind of hemorrhagic stroke often occurs as the result of either two types of weakened arterial vessels: an aneurysm or an arteriovenous malformation (AVM). An aneurysm occurs when a bulge in the blood vessel forms. However, an AVM is the formation of abnormal cells between the arteries and veins. An aneurysm is a weak bulging spot on the wall of an artery in the brain. This is the result of the wearing and tearing of the artery from increased blood flow.
Hemorrhagic stroke may occur when the aneurysm bursts due to high arterial blood pressure. Another way for hemorrhagic stroke to occur is through broken walls of the artery. Increased plaque content in the walls of the artery may decrease in elasticity, making these walls prone to tearing and breakage.

**Reduced Cardiorespiratory Fitness**

Cardiorespiratory fitness reveals one’s ability to carry out moderate- to high-intensity exercise over a prolonged period of time (Whaley, 2006). To measure one’s cardiorespiratory fitness, maximal oxygen consumption, or VO$_2$max, is utilized to assess responses to exercise interventions targeted to improve cardiorespiratory fitness. However, measuring VO$_2$max following a stroke may increase the risk of recurrent stroke, so the highest amount of oxygen consumed, or VO$_2$peak, may be measured as an alternative (Smith, Saunders, & Mead, 2012). Although indirect measurements such as maximal heart rate may be used, the use of open circuit spirometry is more valid. Light to vigorous activities of daily living, or ADLs, have been suggest to require from anywhere between 10.5 to 17.5 milliliters of oxygen per kilogram per minute (Ivey et al., 2006). Also, loss of independence seems likely in those with VO$_2$peak below 15 and 18 milliliters per kilogram per minute in women and men, respectively (Shephard, 2009). Previous research studies have measured VO$_2$peak in individuals post-stroke. Compared to age-and gender-matched individuals, people post-stroke have half the cardiorespiratory values (Billinger, Taylor, & Quaney, 2012; Smith et al., 2012).
Hemiparetic Gait

Hemiparetic gait is a common motor deficit of individuals post-stroke. Immediate impairments critical to gait performance are decreased strength, ill-timed muscle contractions, spasticity and mechanical changes in the properties of the muscles (Olney & Richards, 1996; Dietz & Berger, 1984). These impairments contribute to the various differences in gait pattern between individuals post-stroke and able-bodied individuals. The stride length and cadence of individuals post-stroke has been reported to be lower than that of able-bodied individuals (von Schroeder, Coutts, Lyden, Billings, & Nickel, 1995). Compared to individuals who experience the 60% stance phase and 40% swing phase, individuals post-stroke have different proportions of these two phases. The duration of the stance phase of both limbs is longer compared to that of able-bodied individuals. In addition, individuals post-stroke spend more time in stance phase on their unaffected side relative to their affected side. Another difference in gait between individuals post-stroke and able-bodied individuals is the amount of time spent in double support.

Having the ability to walk independently is one of the main goals of individuals post-stroke (Lord, McPherson, McNaughton, Rochester, & Weatherall, 2004). However, because these gait impairments contribute to hemiparetic gait, functional mobility of these individuals post-stroke is significantly reduced. Although gait speed has been commonly reported to be a critical indicator of walking ability, it is not the only component of independent walking. Fulk et al. (2010) examined the relationship between the six-minute walk test and community ambulation. The six-minute walk test is an outcome measure of walking endurance. 32 participants were recruited for this cross-
sectional design study. Independent variables include the six-minute walk test, Berg Balance Scale, gait speed, lower extremity motor section of the Fugl-Meyer Assessment, and Stroke Impairment Scale, and the dependent variable was the average number of steps taken per day. Similar to the findings of Mayo et al. (1999), the results showed that the six-minute walk test is the most useful predictor of community ambulation in individuals post-stroke. Clinicians may use this knowledge to prescribe exercise programs to people post-stroke and use the six-minute walk test as a functional assessment. However, a limitation to this study is that participants were higher-functioning. Individuals post-stroke in the early stages of rehabilitation should focus on cardiovascular fitness, in order to complete this assessment.

*Treadmill vs. Overground*

Treadmill walking has become increasingly popular for gait rehabilitation in people post-stroke. Various improvements in gait parameters as the result of treadmill walking have been documented (Tyrell et al., 2011). This study examined the influence of systematic increases in treadmill walking speed on gait kinematics after stroke. A total of 20 participants were recruited, 10 people post-stroke and 10 able-bodied individuals. For this cross-sectional study, participants performed treadmill walking at self-selected, fastest and two intermediate walking speeds. Improvements in spatiotemporal gait variables, such as step length of both limbs and support time during single- and double-limb stance, and kinematic gait variables, including hip extension of the paretic limb, trailing limb position and knee flexion during the swing phase. The results demonstrated that walking at faster speeds facilitates improvements in gait parameters without increases in compensating movements, such as circumduction and hip hike. It has been
reported that gait speed is associated with community ambulation, which is highly
desired by the majority of individuals post-stroke (Lord et al., 2004; van de Port et al.,
2008). However, van de Port et al. (2008) also suggests that in addition to gait speed,
other factors, including cardiovascular fitness, contribute to participation in community
ambulation.

Treadmill walking also improves cardiovascular fitness in individuals post-stroke
(Mackay-Lyons, 2012; Macko et al., 2005; Macko et al., 2001). Macko and colleagues
(2005) compared the effects of progressive treadmill exercise to a conventional
rehabilitation program on cardiovascular fitness and ambulatory function. 61 participants
post-stroke with hemiparetic gait were randomly placed into two groups: a progressive
treadmill aerobic exercise and a conventional rehabilitation group. The treadmill aerobic
exercise group completed an intervention of three treadmill exercise sessions per week
for six months, of which progressed in intensity and duration every two weeks, whereas
the conventional rehabilitation group performed 35 minutes of flexibility exercises and
five minutes of treadmill walking at a low intensity. Peak oxygen consumption, 30-feet
walk, six-minute walk, Walking Impairment Questionnaire and Rivermead Mobility
Index were used to assess cardiovascular fitness and ambulatory function before, three
months after and six months after the intervention. Participants in the treadmill aerobic
exercise group demonstrated improvements in cardiovascular fitness, six-minute walk
and Rivermead Mobility Index. The conventional rehabilitation group demonstrated
improvements in gait economy and velocity but not in cardiovascular fitness because
these programs provided only low-intensity exercise, which is not enough to see
adaptations in cardiovascular fitness in individuals post-stroke. These findings suggest
that compared to the conventional rehabilitation program, treadmill aerobic exercise is
more effective in improving cardiovascular fitness, leading to lower energy demands of
hemiparetic gait. According to van de Port et al. (2008), if there are increases in factors
not only in gait speed but also cardiovascular fitness, individuals post-stroke may
increase ambulation function.

Previous research studies have also compared outcomes of treadmill walking to
overground walking (Bayat, Barbeau, & Lamontagne, 2005; Brouwer et al., 2009; Jung et
al., 2013; Park et al., 2010). Bayat and colleagues (2005) compared maximal gait speed
of individuals post-stroke between treadmill and overground walking in a cross-sectional
design study. Ten people post-stroke performed walking at self-selected and maximal
walking speeds, which were measured using a motion analysis system. Spatiotemporal
gait parameters were also assessed. Participants demonstrated greater maximal walking
speeds during overground walking with increased stride length and decreased cadence
when compared to that of treadmill walking.

Another study by Brouwer et al. (2009), using a cross-sectional design, compared
gait parameters and metabolic requirements of treadmill and overground walking in
people post-stroke. 20 participants, ten individuals post-stroke and ten able-bodied
individuals, walked at a matched speed on a treadmill and overground. The results
revealed increases in spatiotemporal gait parameters, including step and stance time, and
in kinematic gait variables, such as interlimb asymmetry and higher vertical ground
reaction force, while walking overground. In addition, at matched speeds, treadmill
walking requires more energy than overground walking, which may already be
challenging for individuals post-stroke in the early stages of rehabilitation or with
moderate to severe disability. If individuals post-stroke already have difficulty walking on land, they may consider walking in water.

Aquatic Exercise

Aquatic exercise has been reported to have a comparable effect on cardiovascular fitness and other areas of health in various populations including people post-stroke (Brubaker, Ozemek, Gonzalez, Wiley, & Collins, 2011; Chu et al., 2004; Hall, Grant, Blake, Taylor, & Garbutt, 2004; Silvers, Rutledge, & Dolny, 2007). An aquatic environment may provide individuals with a more accommodating environment due to the various properties of the water. Chu and colleagues (2004) investigated the effect of an 8-week aquatic group exercise program in people post-stroke. 12 participants were recruited for this intervention. Compared to the control group, the aquatic exercise group demonstrated significant increase in cardiovascular fitness. With the aid of water properties such as buoyancy and viscosity, participants were able to perform moderate- to high-intensity exercises, thus having a significant impact on cardiovascular fitness.

In addition to examining the cardiorespiratory responses to overground and treadmill walking, cardiorespiratory responses to aquatic treadmill walking have also been investigated in both healthy adults and people post-stroke. A study by Schaal et al. (2010) evaluated cardiorespiratory responses between overground and aquatic treadmill running at matched speeds in male triathletes. The 14 participants completed trials at maximal and submaximal effort. Heart rate, rate of perceived exertion, respiratory exchange ratio and oxygen consumption were measured. At maximal effort, both overground and aquatic treadmill running showed no difference in cardiorespiratory responses except maximum heart rate, whereas at submaximal effort, aquatic treadmill
running demonstrated lower oxygen consumption, compared to overground treadmill running. These findings of this cross-sectional design study suggest that aquatic treadmill running is comparable to overground treadmill running only at maximal effort. However, at submaximal effort, due to the lower energy demands, aquatic treadmill running may not be as effective as overground treadmill running to improve cardiorespiratory fitness.

Yoo et al. (2014) examined the difference in cardiovascular responses between overground and an aquatic treadmill walking. Ten participants post-stroke completed two 40-minute sessions, each consisting of five minutes of standing rest on land, five minutes of standing rest on land or in water, 20 minutes of overground or aquatic treadmill walking, five minutes of standing rest on land or water, and five minutes of standing rest on land. This was a comparative cross-sectional design study. Measurements included blood pressure and heart rate. The results showed that the aquatic treadmill walking demonstrated significantly lower average maximum increase in blood pressure and heart rate, compared to overground treadmill walking. Similar to the study by Schaal and colleagues (2010), this suggests that aquatic treadmill walking requires lower energy demands on the cardiovascular system. Although overground treadmill walking has a greater training effect on the cardiovascular system, aquatic treadmill walking provides an effective mode of cardiovascular fitness for people post-stroke in the early stages of stroke rehabilitation who cannot withstand prolonged durations of overground and treadmill walking.

Similarly, Jung et al. (2013) compared energy expenditure between aquatic and overground treadmill walking in people post-stroke. Eight people post-stroke and eight healthy adults completed 8-minute walking sessions on both the aquatic and the
overground treadmills at matched comfortable speeds. Variables of this cross-sectional study measured included oxygen consumption, carbon dioxide production, minute ventilation and energy expenditure. Compared to overground treadmill walking, aquatic treadmill walking demonstrated a significant decrease in mean cardiorespiratory responses. The post-stroke group showed decreases in oxygen consumption, carbon dioxide production, and energy expenditure. Mean minute ventilation did not show any significant difference between aquatic and overground treadmill walking. The results are consistent with those found by Yoo and colleagues (2014). Compared to overground treadmill walking, aquatic treadmill walking demonstrated lower energy demands in people post-stroke. These findings suggest that aquatic treadmill walking may be beneficial for individuals post-stroke whose aims are to functional mobility and gait since individuals post-stroke may withstand durations required for gait rehabilitation. However, aquatic treadmill walking may not be a time-efficient mode of cardiovascular exercise for individuals post-stroke.

Summary

Individuals post-stroke often display poor cardiovascular fitness, compared to age- and gender-matched healthy adults, which may contribute to the reduction of their mobility (Ivey et al., 2006; Mackay-Lyons & Makrides, 2004). This physical inactivity will lead to further deconditioning, which may hinder individuals post-stroke from participating in community ambulation. Previous research has reported improvements in cardiovascular fitness and gait parameters as the result of treadmill, overground and aquatic treadmill walking (Brouwer et al., 2009; Jung et al., 2013; Yoo et al., 2014). Such benefits may lead to increased functional mobility in their ADLs due to lower energy
demands of hemiparetic gait and gait efficiency. Pool floor walking, an alternative mode of exercise, may provide individuals post-stroke with a cost-effective and feasible method to improve cardiovascular fitness and walking ability. However, no studies have examined the energy expenditure of this mode of exercise. The purpose of this study is to compare cardiorespiratory responses between pool floor and overground walking in people post-stroke.
Methods

Participants

Fourteen people post-stroke and 14 healthy controls were recruited from a university-based aquatic therapeutic rehabilitation facility. To participate in this study, individuals post-stroke met the following criteria: medical diagnosis of stroke, minimum of six months post-stroke, physician’s medical clearance, ability to walk independently without assistive devices for a minimum of ten minutes, and ability to understand verbal instructions. Participants were excluded if they had: cardiovascular complication, acute injury or surgery within the last six months. This study protocol was approved by the institutional review board of the university, and informed consent was obtained from all participants. Individuals post-stroke were subject to a Fugl-Meyer Lower Extremity Assessment, and healthy controls to a physical activity readiness questionnaire.

Experimental procedure

All participants completed a six-minute session of PFW and OW on separate days at an aquatic rehabilitation facility. Each exercise session consisted of ten minutes of seated rest and six minutes of walking. Participants came to the laboratory for a total of three visits: an orientation, a walking session in the water and a separate walking session on land.

Prior to the initial visit, participants were asked to bring comfortable exercise clothes, swimming suits and/or trunks, water shoes, and towels to the first visit. The initial visit consisted of anthropometric data collection, blood pressure reading, a Fugl-Meyer Lower Extremity Assessment, and both an aquatic and an overground six-minute walk test for familiarization. PFW sessions were performed in a moveable floor pool. The
temperature of the water was held constant at 92-94 degrees Fahrenheit with the depth of the water adjusted to the xiphoid process of each participant. Before performing PFW, participants rested in a seated position for ten minutes. Following rest, participants were instructed to walk at their fastest speed for six minutes on an oval walkway of 20 meters in a moveable floor pool (KBE Baulemate, GmbH & Co., Wilhelmshaven, Germany). During this walk test, a metronome was used to match the participants’ cadence. Lap times were also recorded. Participants then performed OW in a therapeutic exercise room for six minutes at the speed determined from the aquatic walking session.

Following the first visit, participants returned to the laboratory to perform ten minutes of seated rest and six minutes of PFW at their fastest speed while wearing a telemetric metabolic system (K4b², COSMED Inc., Rome, Italy, 1998). On the third visit, participants performed OW at an equivalent speed determined from the second visit. Lap times and cadence were utilized to control and match the rate at which the participants walked during OW. Cardiorespiratory responses were monitored throughout the protocol.

Outcomes measures

A metronome and verbal prompts were utilized to match cadence and lap times between the two test conditions. A telemetric metabolic system was used to monitor cardiorespiratory responses, including oxygen consumption (VO₂), energy expenditure (EE), and minute ventilation (Vₑ), during rest and walking sessions. Validity and reliability of the portable unit have been established in previous investigations. During PFW, the telemetric metabolic system was kept in a waterproof container, which followed the participant. While performing OW, participants wore a harness to secure the portable unit to their chest.
Data analysis

Mean cardiorespiratory values based on the six minutes of PFW and OW were calculated. Cardiorespiratory variables measured included oxygen consumption, energy expenditure, and minute ventilation. To compare cardiorespiratory responses between PFW and OW within each group, paired t-tests were conducted. A 2x2 mixed model analysis of variance was used to assess main effects between groups (post-stroke group and control group) by condition (PFW and OW). For further analysis, the participants post-stroke were evenly divided into two subgroups (slow walker and fast walker) based on median of their maximum speed. Independent t-tests were used to compare cardiorespiratory responses within each subgroup. P-values were adjusted by Bonferroni correction. Statistical analyses were performed using SPSS software, version 22.0 (IBM SPSS Statistics 22, Armonk, NY, USA).
Results

A total of 28 participants, 14 individuals post-stroke and 14 healthy controls, completed this study. Participants’ demographics are displayed in Table 1. People post-stroke did not show significant differences in cardiorespiratory responses between PFW and OW. However, the control group elicited significant increases in mean VO$_2$, EE and V$_E$ values (all $p<0.05$) during PFW when compared to OW. A 2x2 mixed model ANOVA showed a significant group x condition interaction; the control group increased VO$_2$ from OW to PFW while the post-stroke group did not.

Means and standard deviations of participants’ walking speed are shown in Table 2. Participants performed both PFW and OW for six minutes at a matched speed, which was determined by the average of fastest PFW speed. The walking speed of the control group (0.58±0.11 m/s) was significantly greater than that of the post-stroke group (0.42±0.13 m/s, $p<0.00$).

The means and standard deviations of cardiorespiratory responses are shown in Table 3. Paired t-tests for within-group comparisons revealed no significant differences in cardiorespiratory responses between PFW and OW in individuals post-stroke. However, healthy controls demonstrated significant increases in mean VO$_2$ values by 80% (from 8.03±1.78 to 14.44±4.10, $p<0.00$), mean EE values by 98% (from 2.71±0.92 to 5.35±2.03, $p<0.00$), and mean V$_E$ values by 67% (from 16.43±5.63 to 27.41±10.12, $p<0.00$) while performing PFW when compared to OW (Figure 1).

For further analysis, the post-stroke group was divided into two subgroups based on the median of their fastest walking speeds (0.46 meters per second): fast walker subgroup (n=7) and slow walker subgroup (n=7). The averaged PFW speed of the fast
walker subgroup was 0.52±0.04 meters per second whereas the averaged PFW speed of the slow walker subgroup was 0.32±0.10 meters per second. Although no significant differences were found between PFW and OW in the post-stroke group, statistically significant differences were found following analysis of the subgroups (Table 4). The slow walker subgroup showed significant decreases in mean VO$_2$ values by 20% (from 9.55±1.13 to 7.69±1.45, $p<0.01$), mean EE values by 19% (from 3.73±1.11 to 3.01±1.05, $p<0.01$), and mean $V_E$ values by 11% (from 21.57±6.57 to 19.12±5.86, $p<0.05$) during PFW compared to OW before Bonferroni adjustments were made. However, once the level of statistical significance was adjusted by Bonferroni correction, only mean VO$_2$ and EE values were significantly different between the two conditions. The fast walker subgroup showed no significant differences between conditions.

A significant group x condition interaction was found in VO$_2$ ($p<0.01$, $d=1.94$). The control group increased VO$_2$ between the two walking conditions while the post-stroke group did not. No significant group x condition interaction was found in EE or $V_E$. 

Table 1. Participants’ information

<table>
<thead>
<tr>
<th>Measure</th>
<th>Stroke</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>58.00±15.51</td>
<td>58.79±15.16</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>169.6±5.98</td>
<td>171.30±10.02</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>82.90±13.73</td>
<td>71.94±15.38</td>
</tr>
<tr>
<td>Gender (M/F)</td>
<td>9/5</td>
<td>9/5</td>
</tr>
<tr>
<td>Years post-stroke</td>
<td>5.57±3.57</td>
<td>N/A</td>
</tr>
<tr>
<td>Affected side</td>
<td>R/L</td>
<td>N/A</td>
</tr>
</tbody>
</table>

M = male; F = female; R = right; L = left; LA = lower extremity assessment.
Mean ± standard deviation.

Table 2. Walking speed of post-stroke and control groups

<table>
<thead>
<tr>
<th>Measure</th>
<th>Stroke</th>
<th>Control</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking speed (m/s)</td>
<td>0.42±0.13</td>
<td>0.58±0.11</td>
<td>0.00</td>
</tr>
</tbody>
</table>

M/s = meters per second. Mean ± standard deviation.

Table 3. Cardiorespiratory responses during walking sessions

<table>
<thead>
<tr>
<th>Measure</th>
<th>Stroke</th>
<th>Control</th>
<th>p-value</th>
<th>Stroke</th>
<th>Control</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO_2 (ml/kg/min)</td>
<td>9.40±2.88</td>
<td>9.33±2.69</td>
<td>0.94</td>
<td>8.44±1.60</td>
<td>16.36±4.23</td>
<td>0.00</td>
</tr>
<tr>
<td>EE (kcal/min)</td>
<td>3.84±1.46</td>
<td>3.81±1.35</td>
<td>0.94</td>
<td>3.06±0.96</td>
<td>6.37±2.24</td>
<td>0.00</td>
</tr>
<tr>
<td>V_E (l/min)</td>
<td>22.24±8.62</td>
<td>23.97±8.24</td>
<td>0.38</td>
<td>17.43±5.34</td>
<td>34.93±14.22</td>
<td>0.00</td>
</tr>
</tbody>
</table>

VO_2 = oxygen consumption; EE = energy expenditure; V_E = minute ventilation.
Mean ± standard deviation.

Table 4. Cardiorespiratory responses of post-stroke subgroups

<table>
<thead>
<tr>
<th>Measure</th>
<th>Slow walkers</th>
<th>Fast walkers</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO_2 (ml/kg/min)</td>
<td>Overground</td>
<td>Aquatic</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>9.55±1.13</td>
<td>7.69±1.45</td>
<td></td>
</tr>
<tr>
<td>EE (kcal/min)</td>
<td>Overground</td>
<td>Aquatic</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>3.73±1.12</td>
<td>3.01±1.05</td>
<td></td>
</tr>
<tr>
<td>V_E (l/min)</td>
<td>Overground</td>
<td>Aquatic</td>
<td>0.05</td>
</tr>
</tbody>
</table>

VO_2 = oxygen consumption; EE = energy expenditure; V_E = minute ventilation.
Mean ± standard deviation.
Figure 1. Cardiorespiratory responses during walking sessions

Panel a) oxygen consumption, b) energy expenditure, c) minute ventilation, and d) group x condition interaction of VO₂.
PFW = pool floor walking; OW = overground walking.
Means.
* represents significant difference between aquatic and overground conditions (p<0.01).
Discussion

The study aimed to investigate differences in cardiorespiratory responses to pool floor and overground walking in individuals post-stroke as well as in healthy adults. Our results showed that individuals post-stroke did not expend more energy during pool floor walking when compared to overground walking. However, healthy adults demonstrated greater energy expenditure while walking in water compared to on land. The secondary purpose was to compare differences in cardiorespiratory responses to walking conditions between individuals post-stroke and healthy adults. Our findings revealed that there was a significant between-group difference in oxygen consumption across the two walking conditions. Healthy adults increased their oxygen consumption while walking in water whereas individuals post-stroke did not.

Walking speed

Our results showed that the averaged fastest of pool floor walking speeds of individuals post-stroke and healthy adults were significantly different. People post-stroke walked significantly slower than the healthy adults. Our findings are consistent with a previous study, which reported that people post-stroke selected slower walking speed during aquatic treadmill walking as compared to healthy adults (Jung et al., 2014). Although limited studies have examined walking speed in water, several studies have documented that people post-stroke have slower overground walking speeds than their healthy counterparts (Dean et al., 2001; von Schroeder et al., 1995).

Cardiorespiratory responses to walking

Participants post-stroke did not show significant differences in variables between pool floor and overground walking. Our findings indicate that walking in water requires
energy expenditure similar to that of walking overground at matched speed in individuals post-stroke. This is inconsistent with another study that found lower cardiorespiratory responses during aquatic treadmill walking with water depth also set at the xiphoid process (or chest) compared to that of overground treadmill walking at matched speeds (Jung et al., 2014). Although our study protocol also required participants to walk with water level set at the chest to support 70-80% of their body weight, participants post-stroke did not expend less energy during pool floor walking when compared to overground walking. Even with the effects of buoyancy that provided body weight support, participants had to propel their bodies through the water, creating greater drag force, which may have demanded higher energy expenditure (Pohl & McNaughton, 2003). The effects of buoyancy appeared to counteract the effects of drag force, which may have contributed to no difference in energy expenditure between the two conditions.

When divided into two subgroups based on the median of fastest walking speed (0.46 meters per second), the slow walker subgroup demonstrated significantly lower cardiorespiratory values while walking in water when compared to walking on land. This finding indicates that people post-stroke who walk at slower speeds consume less energy while walking in water. According to the hydrodynamic principle, drag force is greatly affected by movement velocity, in addition to surface area, water density, and drag coefficient, \( F_d = \frac{1}{2} C_d \rho A v^2 \) (Alexander, 1977). The slow movements of people post-stroke can create lower drag force, which may have resulted in lower energy expenditure. In this case, the body weight support from the buoyancy may have had a greater influence on energy expenditure than the effects of drag force did (Alberton et al., 2009, 2005). Our finding is similar to a study by Jung et al. (2014) that found lower cardiorespiratory
responses during aquatic treadmill walking compared to that of overground treadmill walking. Both aquatic treadmill and pool floor walking provide an ideal environment to exercise for prolonged durations without early onset of fatigue. However, an aquatic treadmill may not be readily available or cost-effective for individuals post-stroke as it is not commonly seen in aquatic rehabilitation facilities. Pool floor walking can be an optimal option for people post-stroke in the early stages of gait rehabilitation.

When comparing differences in cardiorespiratory responses to pool floor and overground walking, healthy adults significantly increased cardiorespiratory values while walking in water. Walking at faster speeds increased drag force, which required greater energy expenditure in healthy adults (Alberton et al., 2009, 2005). Our findings are inconsistent with several studies that reported lower cardiorespiratory responses to aquatic treadmill walking compared to overground treadmill walking in people with rheumatoid arthritis and stroke (Yoo et al., 2014; Jung et al., 2013; Schaal et al., 2012; Hall et al., 2004). However, aquatic treadmill walking is considered as stationary ambulation, in which only the legs propel through the water. In the present study, healthy controls performed pool floor walking, which required forward locomotion through the water. They had to propel not only their legs but their full bodies forward to travel through the water, which may have contributed to the increase in cardiorespiratory responses. Another study by Alberton and colleagues (2011) reported greater energy expenditure during stationary running at submaximal and maximal effort on land compared to that in water. This is inconsistent with our findings possibly due to the differences in methodology. The exercises of the previous study involved running in place, whereas the exercises of the present study involved forward locomotion.
The fast walker subgroup did not show significant differences in cardiorespiratory responses to pool floor and overground walking. However, further analysis revealed that fast walkers with similar speeds to that of the control group significantly increased cardiorespiratory responses while walking in water compared to overground. Their walking speed was greater than 0.5 meters per second, which may have led to the effects of drag force outweighing that of buoyancy, similar to what was found in the control group.

Compared to individuals post-stroke who did not exhibit significant differences between conditions, healthy adults demonstrated a greater difference in oxygen consumption between the two walking conditions. Jung and colleagues (2014) reported no significant between-group differences in cardiorespiratory values between people post-stroke and healthy adults across the conditions, which is inconsistent with our findings. The significant group x condition interaction in oxygen consumption may be related to the difference in walking speed between the two groups. Compared to people post-stroke, healthy adults walked at faster speeds in the water, increasing the drag force during pool floor walking, thus showing a greater difference between the two walking conditions.

Limitations and future studies

We acknowledge that there are limitations in the study. The sample size was relatively small, which may have limited the clinical interpretation and generalizability of our findings. Another limitation is that we recruited individuals post-stroke with higher functional mobility. It is recommended that future studies include individuals post-stroke with a wide range of functional mobility. Regarding our methodology, this study
examined cardiorespiratory responses to pool floor walking only in chest-depth water. Future studies should consider examining the influence of various water depth and speeds on cardiorespiratory responses to pool floor walking.

Conclusion

Our results indicate that individuals post-stroke show no difference in energy expenditure between the conditions. Lower energy expenditure can be expected during pool floor walking when the walking speed is slow while greater energy expenditure may be seen during fast walking. The findings suggest that pool floor walking can provide individuals post-stroke in the early stages of rehabilitation with a supportive environment, allowing longer durations of gait training without early onset of fatigue. Healthy adults and faster walking individuals post-stroke may consider pool floor walking as a time-efficient method of cardiorespiratory exercise.
References


APPENDIX A

California State University, Northridge

Comparison of cardiorespiratory responses between pool floor and overground walking in people post-stroke

INFORMED CONSENT

Introduction

You are being asked to participate in a research study. Participation in this study is completely voluntary. Please read the information below and ask questions about anything that you do not understand before deciding if you want to participate. A researcher listed below will be available to answer your questions.

Purpose of the Study

The purpose of this research study is to examine cardiorespiratory responses between pool floor and overground walking in people post-stroke.

Subject Information

For people post-stroke, you are eligible to participate in this study if you have a medical diagnosis of stroke, minimum of six months post-stroke, age of 18 years minimum, physician’s medical clearance, ability to walk in water and on land for ten minutes, ability to understand and follow verbal instructions and
no severe cognitive and emotional impairments that would interfere with research protocol.

For people without stroke, you are eligible to participate in this study if you have an age of at least 18 years minimum, completion of PAR-Q, ability to perform pool floor and land walking for 10 minutes, and ability to understand and follow verbal instructions.

This study will involve approximately one hour per visit over the course of three days, which will approximate to three hours of your time.

**Procedures**

Prior to this visit, you were instructed to bring comfortable exercise-clothing, shoes, swimming suits and/or trunks, and towels to this visit and was informed of the procedure and protocol of this study and the risks associated with cardiovascular fitness. You will be asked to sign this consent form as well as a “Bill of Rights.” Next, if you are participating in the post-stroke group, you will present your medical history and clearance form from a licensed primary physician. If you are participating in the control group, you will complete a PAR-Q.

Afterwards, baseline heart rate, blood pressure and biometric data (height, weight, BMI and age) will be recorded. Your functional ability will be assessed using a Fugl-Meyer lower
extremity motor assessment.

After the lower extremity assessment, you will complete a six-minute walk test in water to determine your walking speed. You will be instructed to change into your swimming suit and/or trunk and water shoes, provided by the researcher. Before performing the walk test, you will rest in a seated position for ten minutes. Water and additional rest will be given if needed. You will be asked to walk for six minutes at your fastest walking speed. The depth of the water will be adjusted to height of the base of your breastbone as the pool floor will move accordingly. After the walk test in the water, you will then be instructed to change into your comfortable exercise-clothing. You will continue wearing the same water shoes for the six-minute walk test on land. If you need to use an assistive device, you will be allowed to use it in both conditions. You will be given ten minutes of seated rest. Water and additional rest will be given if needed. Following the rest, you will be asked to perform six-minute walk test on land. The rate at which you will walk during this test will be determined from the maximum walking speed determined from the initial walking test performed in water. If you feel any abnormal discomfort, the walk test will be terminated upon your request. At the end of the visit, we will schedule the date of the second visit, and you will be asked to
bring the items necessary for the walk test during the second visit. The condition under which you will walk during the next visit will be randomized. If you are randomized to perform the walk test on land during the second visit, you will be asked to bring comfortable exercise-clothing to the second visit. If you are randomized to perform the walk test in water during the second visit, you will be asked to bring swimming suits and/or trunks and towel to the second visit. You will be instructed to not consume any caffeine or alcohol at least three hours prior to the second visit. This visit will approximately last for 90 minutes.

In the second visit, you will be instructed to rest in a seated position for ten minutes and walk under a condition (water or land) for six minutes at the speed determined from the initial visit while wearing the telemetric metabolic system. A sanitized mask will be attached to your face, and you will breathe into the mask. This system will measure how much oxygen and energy your body uses as you walk. A blood pressure cuff will be attached to your upper arm to record blood pressure during seated rest.

If you were randomized to perform the walk test on ground during this visit, you will be instructed prior to this visit to bring comfortable exercise-clothing to this visit. If you were randomized to perform the walk test in water during this visit,
you will be instructed prior to this visit to bring swimming suits and/or trunks to this visit. If you need to use an assistive device, you will be allowed to use it in both conditions. The rate at which you will walk during this test will be determined from the walking speed determined from the initial aquatic walking test from the first visit. The matched speed will be paced by a metronome. Distance walked, lap times and step rate will be recorded. If you feel any abnormal discomfort, the walk test will be terminated upon your request. At the end of the visit, we will schedule the date of the third visit, and you will be asked to bring the items necessary for the walk test during the third visit under the condition you have yet to complete. If you were randomized to perform the walk test on land during the second visit, you will be asked to bring swimming suits and/or trunks and towel to the third visit. If you were randomized to perform the walk test in water during the second visit, you will be asked to bring comfortable exercise-clothing to the third visit. You will be instructed to not consume any caffeine or alcohol at least three hours prior to the third visit. This second visit will take about 45 minutes to complete.

On the last visit, you will be instructed to perform ten minutes of seated rest and another six minutes of walking under the condition you have yet to walk (water or land) while wearing the
telemetric metabolic system. You will follow the same protocol as you did during the second visit. This last visit will be completed in about 45 minutes.

**Risks**

The possible risks and/or discomforts associated with the procedures described in this study include: falling, drowning, cardiovascular complications such as collapse and, in rare instances, death, dehydration, physical fatigue, pain, soreness, muscle cramps, muscle spasms, and other water safety issues. Medical clearance from your physician will be required in order to participate in this study. You will be allowed to rest and drink water when necessary to prevent physical fatigue and dehydration during the walking session. You will be actively spotted by a research assistant. Also, a certified lifeguard will be present during pool floor walking sessions to ensure your safety. CPR/AED and first aid certified research assistants will aid in procedures. If you show abnormal signs or symptoms listed above, data collection procedure will cease immediately and first aid procedure will follow. Emergency services (911) will be contacted. This study involves no more than minimal risk. There are no known harms or discomforts associated with this study beyond those encountered in normal daily life.
Benefits

Society may benefit from the understanding the significance of this study. The findings of this study may show which walking condition (land or water) is a feasible and effective method to improve cardiovascular fitness and walking ability in individuals post-stroke with elevated energy cost. With improvements in cardiovascular fitness, people post-stroke may increase functional mobility, which may lead to an increase of participation in the community.

Compensation, Costs, and Reimbursement

You will not be reimbursed for any out of pocket expenses, such as transportation fees.

You will be responsible for the following cost: transportation fees. Parking passes will be provided by the Center of Achievement.

Withdrawal

You are free to withdraw from this study at any time. If you decide to withdraw from this study you should notify the research team immediately. The research team may also end your participation in this study if you do not follow instructions, miss scheduled visits, or if your safety and welfare are at risk.

Confidentiality

All identifiable information that will be collected about you will be removed and replaced with a code. A list linking the code
and your identifiable information will be kept separate from the research data. This will be placed in a locked file cabinet located in the office of the faculty advisor named on the first page of this form. Only the primary investigator, Brenda Jeng, and faculty advisor, Dr. Taeyou Jung, will have access to these files.

All research data, hard and digital copies, will be stored in a secure computer with password protection and a locked cabinet in two separate offices at the Center of Achievement.

The researcher and faculty advisor named on the first page of this form will have access to your study records. No research assistants will have access to your information. Any information derived from this research project that personally identifies you will not be voluntarily released or disclosed without your separate consent, except as specifically required by law.

Publications and/or presentations that result from this study will not include identifiable information about you.

The researchers intend to keep the research data for approximately three years and then it will be destroyed. If data will be retained, only the faculty advisor named on the first page of this form will have access to information that will not be identifiable and will be stored in a secure password-protected computer and a locked cabinet.
Concerns
If you have any comments, concerns, or questions regarding the conduct of this research please contact the research team listed on the first page of this form.

If you are unable to reach a member of the research team listed on the first page of the form and have general questions, or you have concerns or complaints about the research study, research team, or questions about your rights as a research subject, please contact Research and Sponsored Projects, 18111 Nordhoff Street, California State University, Northridge, Northridge, CA 91330-8232, or phone 818-677-2901.

Voluntary Participation
You should not sign this form unless you have read it and been given a copy of it to keep. Participation in this study is voluntary. You may refuse to answer any question or discontinue your involvement at any time without penalty or loss of benefits to which you might otherwise be entitled. Your decision will not affect your future relationship with California State University, Northridge. Your signature below indicates that you have read the information in this consent form and have had a chance to ask any questions that you have about the study.
CONSENT

I agree to participate in the study.

___________________________________________________  __________________
Participant Signature  Date

___________________________________________________
Printed Name of Participant

___________________________________________________  __________________
Researcher Signature  Date

___________________________________________________
Printed Name of Researcher
### APPENDIX B

**FUGL-MEYER ASSESSMENT**

**ID:**

**LOWER EXTREMITY (FMA-LE)**

Assessment of sensorimotor function

Examiner:


<table>
<thead>
<tr>
<th>E. LOWER EXTREMITY</th>
<th>I. Reflex activity, supine position</th>
<th>none</th>
<th>can be elicited</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexors: knee flexors</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Extensors: patellar, Achilles</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>II. Volitional movement within synergies, supine</th>
<th>non</th>
<th>partial</th>
<th>full</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexor synergy: Maximal hip flexion (abduction/external rotation), maximal flexion in knee and ankle joint (palpate distal tendons to ensure active knee flexion).</td>
<td>Hip flexion Knee flexion Ankle</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Extensor synergy: From flexor synergy to the hip</td>
<td>Hip extens on add</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>III. Volitional movement mixing synergies, sitting position, knee 10cm from the edge of the chair/bed</th>
<th>non</th>
<th>partial</th>
<th>full</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee flexion from actively or passively extended knee</td>
<td>no active motion</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>no flexion beyond 90°, palpate tendons of hamstrings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee flexion beyond 90°, palpate tendons of</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ankle dorsiflexion compare with</td>
<td>no active motion</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>limited dorsiflexion</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Subtotal I (max 4)

Subtotal II (max 14)

Subtotal III (max 4)
### IV. Volitional movement with little or no synergy, standing position, hip at 0°

<table>
<thead>
<tr>
<th>Movement</th>
<th>non</th>
<th>partial</th>
<th>full</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Knee flexion to 90°</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip at 0°, balance support is allowed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no active motion / immediate and simultaneous hip flexion</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>less than 90° knee flexion or hip flexion during movement at least 90° knee flexion without simultaneous hip flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ankle dorsiflexion</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compare with unaffected side</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no active motion</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>limited dorsiflexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>complete dorsiflexion</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Subtotal IV (max 4)

### V. Normal reflex activity supine position, evaluated only if full score of 4 points achieved on earlier part

<table>
<thead>
<tr>
<th>Reflex activity</th>
<th>non</th>
<th>partial</th>
<th>full</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee flexors, Achilles, patellar</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>0 points on part IV or 2 of 3 reflexes markedly hyperactive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 reflex markedly hyperactive or at least 2 reflexes lively maximum of 1 reflex lively, none hyperactive</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Subtotal V (max 2)

**Total E (max 28)**

---

### E. LOWER EXTERMTY

/28

### F. COORDINATION / SPEED

/6

**TOTAL E-F (motor function)**

/34
APPENDIX C

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Do you feel pain in your chest when you do physical activity?</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>In the past month, have you had chest pain when you were not doing physical activity?</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Do you lose your balance because of dizziness or do you ever lose consciousness?</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart conditions?</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Do you know of any other reasons why you should not do physical activity?</td>
<td></td>
</tr>
</tbody>
</table>

If you answered YES to one or more questions, talk with your doctor or phone or in person before you start becoming much more physically active or before you have a fitness appraisal. Let your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to be active. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 140/90, talk with your doctor before you start becoming much more physically active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professionals. Ask whether you should change your physical activity plan.

Laboratory Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

Name: ____________________________ Date: ____________

Signature: ____________________________

Co-Parent or Guardian (for participants under the age of majority):

Name: ____________________________

Date: ____________

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.