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Correlating Heart Rate and Perceived Exertion during Aerobic Exercise in Alzheimer's Disease

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Abstract

Older adults reap many health benefits from aerobic exercise training; however, little is known about how to monitor training responses in older adults with Alzheimer's disease. The purpose of this paper was to examine the correlation of objectively measured heart rate and subjectively reported perceived exertion during aerobic exercise training in four older men with advanced Alzheimer's disease from a pilot study that used a one-group pre- and post-test design. During training (3 times a week for 8 weeks), participant's heart rate and perceived exertion was assessed by a trained exercise trainer every 5 minutes using Polar™ heart rate monitor and the Borg Rating of Perceived Exertion Scale respectively. There were 596 heart rate-perceived exertion data pairs. The results show that Pearson's *r* for heart rate and perceived exertion was .457, significant at .01, 2-tailed, controlling for age, education, exercise session, and cognition. We conclude that the Borg scale itself might be insufficient for monitoring exercise responses in older men with advanced Alzheimer's disease. Future studies are needed to further examine the utility of the Borg scale in this population.

Keywords

aging; Alzheimer's disease; dementia; exercise; perceived exertion

Introduction

Alzheimer's disease (AD) is a neurodegenerative disease that affects about five million Americans and is the sixth leading cause of death in the U.S. (Hebert et al., 2003). As the baby boomer generation cross over into older adulthood in the following decades, ten million of these older adults will likely develop AD (Hebert et al., 2003, Qiu et al., 2009). AD's pathological plaques and tangles slowly destroy neurons and create abnormalities, resulting in impaired global cognition, memory, executive function, language, visuospatial function, physical function, and increased psychological and behavioral symptoms of dementia. Currently there is no cure for AD (American Psychiatric Association, 2000); however, regular aerobic exercise might improve the quality of life and slow the rate of decline for persons with AD (Yu et al., 2006).

Aerobic exercise involves using large muscle groups to cause heart rate (HR) to increase for an extended period of time (American College of Sports Medicine, 2006). Older adults are

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recommended to participate in 20 to 60 minutes of aerobic exercise with an intensity of 55% to 65% but up to 90% of an individual's maximum HR on most days of the week (American College of Sports Medicine, 2006). Aerobic exercise has many established benefits to older adults such as increased functional independence and quality of life and decreased all-cause mortality (Vogel et al., 2009). Aerobic exercise is further shown to decrease AD neuropathology in transgenic mice (Adlard et al., 2005), relating to a delayed onset and reduction in incidents of dementia and AD in humans (Fratiglioni et al., 2004, Larson et al., 2006, Rovio et al., 2005, Kwak et al., 2008). Improvements in cognition and function have also been reported in older adults with and without dementia who participated in aerobic exercise (Colcombe & Kramer, 2003, Heyn et al., 2004). Nonetheless, little is known about how to monitor aerobic exercise training responses to ensure safety in older adults with AD.

Study Aim

The aim of the pilot study was to examine the feasibility of engaging older adults with advanced AD in 2-month, moderate intensity aerobic exercise training. Data used for this paper were generated from the aerobic exercise training. The purpose of this paper was to examine the correlation of objectively measured HR and subjectively reported perceived exertion during aerobic exercise training in four older men with advanced AD.

Review of the Literature

Due to the aging process, older adults have a decrease in cardiovascular function and muscle mass as well as difficulties with balance and mobility that put them at a higher risk for exercise-related injuries. The American College of Sports Medicine (ACSM) recommends that aerobic exercise should be medically supervised, low impact with longer warm-up and cool-down periods, and its duration and intensity should increase very slowly (American College of Sports Medicine, 2006). Aerobic exercise training in older adults with AD is likely to be even more challenging compared to those without AD. Individuals with intact cognition can subjectively and accurately assess and report their perceived exertion; thus, they can self adjust their exercise intensity and duration volitionally: push themselves harder when they are not physically exerted enough and decrease exercise levels when they know they are at their limits. Older adults with AD, on the other hand, might not be able to make those adjustments due to impaired judgment, awareness, and insights as well as increased communication difficulties.

Traditionally, HR and subjective rating of perceived exertion have been used to monitor aerobic exercise responses and gauge aerobic exercise training progress. HR could be monitored via three ways: pulse palpation, HR monitors, and auscultation of apical HR. Pulse palpation requires only a watch with a second hand. HR monitors vary depending on the make and model, but most provide a continuous HR reading. One type of HR monitor is a Polar™ monitor that includes a belt containing electrodes that fits around an individual's chest and transmits HR readings to a wrist unit receiver (Bassett, 2000). Auscultation of apical HR requires a stethoscope and a watch with a second hand (Adams, 2002).

Perceived exertion is a subjective perception where exercisers report their body's exertion. The Borg Rating of Perceived Exertion (RPE) Scale was very well established and the most widely used scale for measuring perceived exertion during exercise. Perceived exertion was shown to be a valid construct because individuals with no cognitive impairment are able to correctly interpret HR, breathing discomfort, and metabolic signals from the body and adapt their aerobic exercise to maintain a specific level of intensity both consciously and subconsciously (Robertson, 1982). Another study examined 28 healthy males in good physical condition and compared their HR, blood lactate, leg pain, and RPE using the RPE scale during exercise on a cycle ergometer. Findings suggested a strong correlation between

RPE and HR (r = .91 when p < .0001), demonstrating a linear relationship (Borg et al., 1985). Dawes et al. (2005) further investigated if the Borg-RPE scale ratings varied by clinical groups: 19 participants with brain injury, 16 with chronic lower back pain, and 20 healthy individuals. They found that the RPE ratings by the healthy and chronic lower back pain groups were similar; however, the brain injury group had more variance in their understanding of the verbal anchors in the scale. This variance could indicate that individuals with brain injury may not be able to use the RPE scale to accurately determine their perceived exertion (Dawes et al., 2005). Since older adults with AD experience brain injury related to AD neuropathology, it is of great clinical importance to understand whether perceived exertion can be used in this population as a way to monitor exercise responses.

Methods

Research Design

A one group pre- and post-test design was used to progress four community-dwelling older men with advanced AD through an aerobic exercise training program from a pilot study. The aerobic exercise training was 8-weeks, moderate intensity cycling on recumbent stationary cycles (Precor™) three times a week at the Laboratory of Physical Hygiene and Exercise Science at the University. The study was approved by the University of Minnesota Institutional Review Board. Surrogate consent was obtained from spouses while assent was obtained from participants.

Sample and Setting

Participants were recruited through newspaper advertisements and presentations at AD support groups by the first author FY. Twenty people responded and were screened of which four participants from two local support groups met the eligibility criteria and completed the training program. The inclusion criteria were: age > 60 years old; live in the community; have an AD diagnosis by a healthcare provider; understand and speak English; and have a resting HR < 100 beats per minute (bpm). The exclusion criteria included: nursing home residents; dementia other than AD; psychiatric illness, alcohol or chemical dependency within the past five years; unstable medical conditions within the past 6 months, e.g., heart attack, angina, or stroke; hip fracture, repair, replacement, or surgery within the last 6 months; on HR altering medications; physician's order against exercise participation; symptoms that have not been reported to physicians, e.g., chest pain, irregular heart rate, weight loss, shortness of breath; and electrocardiogram (ECG) readings indicative of unknown heart disease during screening exercise testing.

Procedures

A 3-step screening process was used to qualify potential participants. First, an undergraduate nursing student, who was trained by FY, obtained a potential participant's health history via a structured phone interview with the caregiver. Second, those who had a diagnosis of AD by a healthcare provider and no contraindications for aerobic exercise were invited for an in-person interview at the University General Clinical Research Center (GCRC) with FY. FY corroborated the health history, signs and symptoms, and medications with the participant and caregiver. Last, baseline HR and blood pressure (BP) was taken by a GCRC nurse for those potential participants. FY summarized the health history to the cardiologist who supervised the screening exercise testing and evaluated the participant's HR, BP, and ECG responses to graded cycle ergometer exercise testing and determined the final eligibility of the participant.

Enrolled participants cycled 3 times a week for 10 to 30 minutes at moderate intensity on a recumbent stationary cycle under the guidance and supervision of a study exercise trainer.

The exercise trainer had a baccalaureate degree in Arts and Sciences, had been a personal trainer for the past 13 years with a large clientele of older adults, and had cared for a family member with AD. The trainer was trained by FY on understanding and working with older adults with AD and implementing the exercise training protocol until the trainer fully understood the protocol. At each exercise session, the trainer assisted the participant to put on the Polar™ HR monitor chest belt and wrist unit and took pre-exercise HR. The trainer then guided participants to warm up for 5 minutes by modeling range of motion, light stretching of lower extremities, and marching in place. Participants then mounted the cycle and started a 5 to 10 minute cardiovascular warm-up. The trainer set a low resistance level and asked participants to cycle at a low speed of 20 to 30 revolutions per minute. Resistance and speed were increased alternatively every couple of minutes until the participant reached the target or peak exercise intensity. The trainer then asked the participant to continue at this level for 10 minutes initially while the duration was progressively increased to 30 minutes over sessions based on participant's tolerance.

Measures

HR—HR was objectively measured by a wireless portable Polar™ F11™ Fitness HR Monitor, that includes a coded transmitter and a wrist unit receiver, every five minutes during cycling coinciding with the RPE assessment until the beginning of the cardiovascular cool-down. The coded transmitter is a strap containing electrodes that is placed around the chest and transmits HR signal to the wrist unit receiver in bpm. Bassett (2000) found that Polar™ wireless portable HR monitors were valid during physical activity (r = 1.00). In order for the Polar F11™ to maintain accuracy, the electrodes were wet with water before being placed on the skin and the wrist unit receiver was either on a participant's wrist or on the cycle console within three feet of the coded transmitter. The exercise trainer was trained to assess and document HR by FY via explanation, demonstration, and feedback.

Perceived exertion—Perceived exertion was measured by the Borg RPE scale, which contains both verbal anchors and a numerical scale. The numbers range from 6 to 20 while the verbal anchors start at 6 which is labeled as 'least effort', 7 'very very light', 9 'very light', 11 'fairly light', 13 'somewhat hard', 15 'hard', 17 'very hard', 19 'very very hard', and 20 'maximum effort.' Different colors also pertain to a specific range of the ratings with the color blue for numbers 6 to 9, green for 10 to 14, yellow for 15 to 20, and red for 20. This scale was created so that the numerical rating increases with HR in a linear fashion making it a valid tool to use (Borg et al., 1985). The RPE scale has also been shown to be valid in rating perceived exertion and exercise intensity during aerobic exercise in people who had normal cognition (*r* = .80–.99) (Borg et al., 1985, Borg, 1973, Dawes et al., 2005).

The Borg was administered according to the ACSM guidelines (2006): "During the exercise test we want you to pay close attention to how hard you feel the exercise work rate is. This feeling should reflect your total amount of exertion and fatigue, combining all sensations and feelings of physical stress, effort, and fatigue. Do not concern yourself with any one factor such as leg pain, shortness of breath or exercise intensity, but try to concentrate on your total, inner feeling exertions. Try not to underestimate or overestimate your feeling of exertion; be as accurate as you can." During screening exercise testing, the ACSM instruction for the Borg was read word-by-word to the participant prior to exercise testing; however, we found that participants had trouble understanding it. Subsequently, during exercise training, we applied the ACSM instruction principles and used simplified wording by first eliciting a verbal descriptor for perceived exertion, followed by obtaining a numerical rating corresponding to the verbal descriptor: "I want you to tell me how hard you feel the exercise is… Think about your total feeling of exertion, fatigue, effort, and stress… Do not focus on just leg pain or breathing… Be accurate as you can… Is it (use verbal anchor very light/light/somewhat hard/hard/very hard)… which number reflects your feeling of (the verbal anchor)?" The RPE scale was administered every 5 minutes after the participant started to cycle coinciding with HR assessment, but not assessed once the cardiovascular cool-down began. The exercise trainer was trained to assess and document the Borg RPE scale by FY through explanation, demonstration, and feedback.

Covariates—Exercise session, age, education, and cognition were the covariates. Exercise session was included because of some expected learning effect on using the RPE scale and the HR conditioning effect with training. Exercise session was defined as the number of the training sessions completed. Age referred to the number of years the participant had lived past their birthday and was included due to the aging effect on HR. Education might affect the ability of participants to use the RPE scale and was defined as the number of years of formal schooling. Cognition was included because it influences a person's ability to understand and follow instructions, and was measured by the Mini-Mental State Examination (MMSE: reliability $r = .89$) at baseline (Folstein et al., 1975). Since this study was a pilot work, other unknown factors that might affect the relationship between HR and perceived exertion could not been included.

Data Analysis

All data were entered into an excel database by an undergraduate RA, and double checked by FY for accuracy. Of the 625 data collection points, 623 were recorded for HR and 596 for perceived exertion. Missing data were small in number and random and deleted list-wise, resulting in 596 HR-perceived exertion data pairs for analyses. For RPE that were reported as a range by participants (12.25%), the RPE value was recoded as the median between the ranges.

All statistical analyses were performed in SPSS 17.0 version. Descriptive statistics was performed to describe HR, perceived exertion, and covariates. After ensuring the statistical assumptions were met, bivariate correlation analyses were performed between exercise session, age, education, cognition, HR, and perceived exertion using Pearson's *r*. Partial correlation analysis between HR and perceived exertion was conducted controlling for covariates that correlated with either HR or perceived exertion at a significant level during bivariate analyses.

Results

The average age of the four participants was 70.75 years, ranging 61 to 82 years. Three were white and one was Asian. All participants were male and married and were living with their spouses. They had 18.33 years of education on average (see Table 1).

The average HR was 105.32 bpm (SD = 15.71; range 68–141 bpm), indicating a low-to-moderate intensity of exercise. Perceived exertion averaged 9.58 (between very light and light; SD = 2.42), ranging from 6 (least effort) to 17 (very hard). The bivariate correlational Pearson's *r* for HR and perceived exertion without controlling for any covariates is .384 (significant at .01 level, 2-tailed). Pearson's *r* for education and HR is .476, for age and HR is −.424, for cognition and HR is .448, and for exercise session and HR is .500, all of which are significant at .001 level, 2 tailed. Perceived exertion was significantly correlated to education ($r = -.293$), age ($r = -.174$), cognition ($r = .123$), and exercise session ($r = .357$) at .01 level, 2-tailed. A partial correlation between HR and perceived exertion was significant at .01 level, 2-tailed ($r = .457$) controlling for education, age, exercise session, and cognition.

Discussions

Findings from this study indicated a moderate correlation between HR and subjectively reported perceived exertion in older men with advanced AD, even after controlling for age, cognition, exercise session, and education. The correlation between HR and perceived exertion reported in this study is much less than what has been reported in other populations. In Borg's initial study (1973) with healthy middle-aged men, he found HR and perceived exertion correlations between .80 and .90 when exercising on a cycle ergometer at a light to very hard work intensity level, whereas HR was approximately ten times the RPE values. Another study by Borg (1985) showed the correlation between HR and RPE was .62 and .72 with healthy young-adult males exercising at hard to very hard work. Although we prescribed a moderate-intensity exercise training program, participants exercised mostly at low-to-moderate intensity during training as indicated by the low mean HR (105.32 bpm) and perceived exertion (9.58: between very light and light), which may explain the moderate correlation observed. Further, declining physical condition and AD-induced cognitive impairment could explain the reduced strength of the correlation between HR and perceived exertion in our participants. A study by Dawes et al. (2005) has indicated that people who have had brain damage from an injury had a greater variance in their ratings of perceived exertion compared to healthy individuals. It is highly likely that persons with AD, a neurodegenerative disease, suffer greater difficulty in understanding the verbal anchors of the Borg RPE scale. It is unclear if older men with advanced AD can adequately report their perceived exertion because we did observe sometimes that the reported RPE level did not seem to be consistent with their skin color and moisture, talking ability while cycling, breathing frequency and depth during cycling.

We further found that age had inverse relationships to both HR and perceived exertion, while exercise session, cognition, and education positively related to HR and perceived exertion. Those findings are consistent with the current literature. As people get older, the maximum HR an individual can achieve during exercise decreases with each year (maximum HR = 220 – age). Further, older adults are more likely to be on medications that can depress HR and HR response during exercise such as β blockers. The inverse correlation between age and perceived exertion might be contributable to the fact that older adults, especially males, may tend to downplay their perceived exertion so as not to sound weak. Years of education correlated positively with HR and perceived exertion, suggesting that educational attainment might affect a person's lifestyle and their ability to understand and use the RPE scale. There was a learning effect as reflected by the correlation between exercise session and perceived exertion and a conditioning effect from exercise training as reflected by the correlation between exercise session and HR.

Our simplified instruction for the RPE scale worked most of the time. Sometimes, participants would not give a verbal descriptor, but pointed to a number on the scale directly. Due to impaired memory and learning, we did not expect participants to remember how to report perceived exertion on the Borg. Rather, we treated each administration as new. Occasionally, a participant would ask what their previous rating was or had trouble giving a rating; then the trainer would tell them the previous rating and ask if the exercise had become easier or more difficult and use the verbal responses to reassess the verbal descriptor and a numerical rating. For about 12% of the RPE ratings, participants reported perceived exertion as between two numerical numbers despite our efforts to obtain one number. Hence, a simplified version of the Borg might be easier for older men with advanced AD.

Findings from this study are limited because this was a pilot study where the sample size was small, there was a lack of racial and gender diversity, and uncontrolled factors that might have influenced the relationship between HR and perceived exertion could not be

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examined. The correlation between HR and perceived exertion might be different in older women with AD, although Borg's studies (1973 and 1985) did not suggest a gender difference. In addition, there are numerous other factors that might impact perceived exertion, e.g., racial diversity, specific cognitive impairment that was not controlled for in this study. AD is a complex syndrome that affects different areas of cognition variably in each individual. Despite the lack of relationship between cognition as measured by the MMSE and perceived exertion, specific domains of cognition such as executive function, memory and language might show different results. These factors uncontrolled in our study would need to be scrutinized in large studies.

The unique strength of this study is that it sets a stage for future examination of how to monitor safety during aerobic exercise training in older adults with advanced AD. This study is particularly timely in the context of the growing literature on the positive impact aerobic exercise has on brain structure and function in older adults. It is increasingly recognized that older adults should engage in adequately designed and implemented aerobic exercise on a regular basis. Aerobic exercise for older adults with AD is especially challenging due to their lack of motivation, decreased insights, impaired cognition and increased behavioral and psychological symptoms resulted.

Findings from this study have important implications to nursing and other healthcare professionals. The increasing prevalence of AD means that nurses and other healthcare professionals are likely to encounter patients with AD in their practice. It is important for all clinicians to be aware of the importance of aerobic exercise for older adults with AD as a potential intervention because of its established multifaceted health benefits in older adults. Hence, they could consider helping recommend and implement aerobic exercise programs for older adults with AD. Our findings imply that the RPE alone might not be adequate for monitoring exercise safety in people with advanced AD during low-to-moderate intensity aerobic exercise. Perceived exertion might need to be interpreted in the context of other signs and symptoms such as HR and BP, skin color and moisture, breathing patterns, and talking ability while exercising.

Conclusion

This pilot study found only moderate correlation between HR and subjectively reported perceived exertion in older men with advanced AD during low to moderate intensity aerobic exercise. The findings are limited due to the small sample size and lack of control of other unknown factors that might affect the relationship between HR and perceived exertion, which calls for future studies with larger sample sizes and both genders. Other exercise monitoring methods, such as modified and simplified perceived exertion scales, should also be explored in its utility in older adults with advanced AD.

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Table 1

Demographics of the Sample (n = 4)

	Mean (SD)/Frequency	Range
Age (years)	70.75 (8.77)	61 – 82
Education (years)	18.33 (1.53)	17 – 20
Male gender	100%	
Race Asian Caucasian	25% 75%	
# of exercise sessions completed	23.5	21 – 24
Heart rate (beats per minute)	105.32 (15.76)	68 – 141
Perceived exertion	9.58 (2.42)	6 – 17