Swansea University
Prifysgol Abertawe

Cronfa
Setting Research Free

Cronfa - Swansea University Open Access Repository

This is an author produced version of a paper published in :
Journal of Aging and Physical Activity

Cronfa URL for this paper:
http://cronfa.swan.ac.uk/Record/cronfa26216

Paper:
Legrand, F., Bertucci, W. & Hudson, J. (2016). Acute Effects of Aerobic Exercise on Feelings of Energy in Relation to Age and Sex. *Journal of Aging and Physical Activity, 24*(1), 72-78.

http://dx.doi.org/10.1123/japa.2014-0121

This article is brought to you by Swansea University. Any person downloading material is agreeing to abide by the terms of the repository licence. Authors are personally responsible for adhering to publisher restrictions or conditions. When uploading content they are required to comply with their publisher agreement and the SHERPA RoMEO database to judge whether or not it is copyright safe to add this version of the paper to this repository.
http://www.swansea.ac.uk/iss/researchsupport/cronfa-support/

Acute effects of aerobic exercise on feelings of energy in relation to age and gender.

Abstract

A crossover experiment was performed to determine whether age and sex, or their interaction, affect the impact of acute aerobic exercise on Vigor-Activity (VA). We also tested whether changes in VA mediated exercise effects on performance on various cognitive tasks. Sixty-eight physically inactive volunteers participated in exercise and TV-watching control conditions. They completed the Vigor-Activity subscale of the Profile of Mood States immediately prior to and 2 minutes after the intervention in each condition. They also performed the Trail Making Test 3 minutes after the intervention in each condition. Statistical analyses produced a condition × age × sex interaction characterized by a higher mean VA gain value in the exercise condition (compared to the VA gain value in the TV-watching condition) for young female participants only. In addition, the mediational analyses revealed that changes in VA fully mediated the effects of exercise on TMT-Part A performance.

Keywords: acute aerobic exercise, feelings of energy, cognition, age, sex.

Acute effects of aerobic exercise on feelings of energy in relation to age and gender.

The exercise psychology literature is replete with research that has examined the effects of exercise on mood (for a synthesis, see Buckworth, Dishman, O'Connor, & Tomporowski, 2013). The effects of chronic exercise have been examined in cross-sectional studies (e.g., examining differences in aspects of well-being between groups differing in habitual levels of physical activity) as well as in experimental studies (e.g., examining the effects of weeks or months of exercise-training participation). These have generally concluded that chronic exercise is associated with reduced anxiety, reduced depression, and improved mood state and well-being (Ekkekakis & Backhouse, 2014). These beneficial effects appear to extend to both genders and all age groups. Studies on the effects of single sessions of physical activity have shown that for most individuals, self-reported positive affect is improved at intensities below the ventilatory threshold (VT) or the lactate threshold (LT; Ekkekakis, Parfitt, & Petruzzello, 2011).

That being said, it is prudent to be cautious about overgeneralizing the benefits of moderate-intensity exercise on mood and emotional states because of the large inter individual variability in observed responses. Indeed, several studies carried out in the past 15 years have provided compelling evidence that there is a diversity of individual affective responses to the same exercise stimulus (e.g., VanLanduyt, Ekkekakis, Hall, & Petruzzello, 2000). Thus it might be the case that exercise only positively influences affect in individuals with a genetic composition that includes positive responses to exercise, as suggested by Mogil (1999) who presented evidence that tolerance to pain has genetic bases.

Research conducted recently has paid particular attention to the influence of single sessions of exercise on feelings of energy (e.g., Puetz, 2006), and more globally on positive activated affect (PAA; e.g., Reed & Ones, 2006). PAA is derived from Russell's circumplex model of affect (Russell, 1980) and is the quadrant in the model that refers to affective states of high arousal and high pleasure. The meta-analysis by Reed and Ones (2006) examined previously published research (158 studies published between 1979 and 2005) and revealed significant beneficial effects of acute physical exercise on PAA. The mean corrected effect size was 0.47, indicating that on average, PAA increases by nearly half a standard deviation after a single session of aerobic exercise (whereas it was found to decrease by a margin of approximately 0.2 of a standard deviation in control conditions, such as watching TV). This beneficial effect of exercise was larger for participants who had the lowest pre-exercise scores of PAA, for exercise of low intensity (15 to 39 percent of maximal oxygen uptake reserve), for exercise duration up to 35 minutes, and for mood assessment taken up to 5 minutes post-exercise. Of note, however, is that reported effect sizes had relatively large standard deviations, which led the authors to propose that additional variables may further moderate the effects of exercise on PAA (Reed & Ones, 2006, p. 500). Potential candidates may include gender and age.

With regard to gender, prior research has revealed that mood benefits resulting from exercise appear to be stronger among women than men (e.g., Hamer, Endrighi, & Poole, 2012). The cause for this sex-based difference may relate to the fact that exercise alters mood to a greater extent in participants whose pre-exercise mood is at low to moderate levels, and as suggested in past research, women tend to report more pre-exercise negative mood than men (e.g., Merns, 1995).

In relation to age, even though recent research has found acute exercise to increase high-arousal positive affect (i.e., PAA) across different age groups (Hogan, Mata, & Carstensen, 2013), there has been some suggestion in the literature that the affective benefits resulting from exercise are weaker for older than for younger adults (e.g., Netz, Wu, Becker, & Tenenbaum, 2005). Some studies even reported reductions in PAA following acute exercise in older participants (e.g., Focht, Knapp, Gavin, Raedeke, & Hickner, 2007). One possible indirect explanation for this unfavorable response may be related to the association between advancing age and the increased prevalence of fatigue-inducing diseases (e.g., chronic sleep disorders, coronary heart disease, anemia) that would hinder or even preclude the energy-boosting effect of exercise. Another reason why older individuals exhibit lower energy scores following exercise could be that the discrepancy in fitness between non-exercisers and exercisers is more apparent than in younger individuals (Hoffman & Hoffman, 2008) coupled with evidence that unfit-sedentary individuals generally report lower PAA levels both during and after aerobic exercise (e.g., Bixby & Lochbaum, 2006).

One important implication associated with the energy-boosting effect of exercise is its probable positive contribution to cognitive functioning. This supposition is based on the putative model developed by Spirduso, Spoon, and Chodzko-Zajko (2008, see Figure 1). In this model, exercise is thought to affect both physical and mental resources, which in turn may create optimal conditions for cognitive function. As can be seen, one of the proposed mediating mechanisms is that exercise enhances cognition through its effects on energy levels.

----------------------------------insert Figure 1 about here--

Therefore, the primary purpose of the present study was to examine changes in feelings of energy following a single acute bout of aerobic exercise compared with a non-exercise control condition in a sample of young-old persons (65-74 years old) and a sample of younger adults (18-35 years old). The possible moderating effect of gender was examined. A secondary purpose was to test whether the effect of exercise on cognitive functioning is mediated by changes in levels of energy, as predicted by Spirduso *et al.*'s (2008) model.

Methods

Participants

Thirty-five young adults (mean age 24.77 years, *SD* = 8.84; 16 men and 19 women) and 33 young-old adults (mean age 67.42 years, *SD* = 6.02; 13 men and 20 women) from different areas in northeastern France volunteered to participate in the present study.

Considering our interest in the detection of a sex × age interaction, at least 18 participants per group were required to maintain alpha and beta errors of 5% and 20% respectively (we assumed a high correlation among the repeated measurements of feelings of energy, *r* = 0.70, as well as an effect size of 0.50 for exercise).

Among these 68 participants, 66 were white Caucasians and 2 were from French overseas territories (1 from French West Indies, and 1 from Reunion Island). Participants were healthy on inclusion in the sample. They were considered as physically inactive if they had engaged in two or fewer 30-min bouts of structured physical activity per week during the preceding 6 months. 86% were classified as physically inactive based on one question specifically targeting voluntary aerobic exercise ("On average, how much time per week have you devoted to a session of at least 30 min of aerobic exercise during the last 6 months?"). Informed consent was obtained from each participant before the collection of any data, and we sought to design and conduct the experiment in line with the Declaration of Helsinki and its subsequent amendments.

Instruments

Feelings of energy. Feelings of energy were evaluated using the Vigor-Activity subscale of the Profile of Mood States (McNair, Lorr, & Droppleman, 1992), validated in French by Cayrou, Dickès, Gauvain-Piquart, Dolbeault, Callahan, and Roge (2000). In its French version this subscale includes 7 items and is typified by feelings of alertness, vitality and physical energy (e.g., "I feel energetic", "I feel mentally alert"). It takes about 30 seconds to complete (participants were instructed to rate their mood right now, at this moment, when completing the questionnaire). Responses are recorded on a 5-point continuum from 0 (much unlike this), to 4 (much like this). Psychometric evaluation of the French version of the

POMS has revealed high internal consistency estimates (0.82 $<$ Cronbach’s alphas $<$ 0.92) among both subscales (Cayrou et al., 2000).

Cognitive functioning. The Trail Making Test (TMT, Parts A and B; Reitan & Wolfson, 1985) was used to evaluate various aspects of participants’ cognitive abilities. TMT-Part A requires participants to connect numbers (from 1 to 25) randomly distributed across a page in sequence. In Part B of the TMT, both letters and numbers are presented and respondents are instructed to draw connecting lines while alternating between the numbers and the letters (1, A, 2, B, 3, C, etc.). Completion time (in seconds) was recorded for both Parts A and B. Raw performance on Part A has been denoted as a measure of psychomotor speed and attention, whereas raw performance on Part B reflects a diversity of cognitive functions including visual search skills and working memory. In line with the recommendations by Oosterman *et al.* (2010), the Part B/Part A ratio was used as an indicator of mental flexibility. Mental flexibility is a fundamental component of cognitive (“executive”) control and refers to an ability to adapt cognitive behavior to changing contexts in order to maximize success in a particular cognitive task. It is generally thought to depend on the integrity of the prefrontal cortex, and is highly sensitive to age-related changes in the brain and cognitive function (Oosterman *et al.*, 2010).

Procedure

This study used a within-subjects cross-over design in which all the participants completed an exercise and a TV-watching (control) condition. Each of these conditions consisted of the following sequence: pre-condition testing (Vigor-Activity subscale), intervention (exercise or TV-watching), 2 minutes rest, post-condition testing (Vigor-Activity subscale, TMT-Part A, TMT-Part B). Participants were scheduled for an exercise condition and a TV-watching condition with the order of conditions randomly assigned. They were asked to refrain from intense exercise for at least 24 hours before their participation in each study condition. Both conditions were performed at the same time of day for each participant (± 2 hours), were separated by a 4-7 day interval, and each were approximately 50 minutes in duration.

Exercise condition. Participants reported to the laboratory where they first read and signed a university-approved consent form and were fitted with a heart rate (HR) monitor (Polar RS800, Kempele, Finland). They then completed the pre-exercise Vigor-Activity subscale, after which resting heart rate was assessed. Target HR value was determined using the heart rate reserve method (HRR; Karvonen, Kentala, & Mustala, 1957). In line with the recent ACSM recommendation (ACSM, 2010) maximal HR (HR_{max}) was calculated from the following equation: $HR_{max} = 206.9 – 0.67*age$. Based on Swain and Leutholtz (1997) and Swain, Leutholtz, King, Haas, and Branch (1998), percentage in the HRR formula was adjusted from .60 to .57 to more accurately estimate the target HR for 60% VO_{2max}. Exercising at 40%-60% of HRR corresponds to "moderate" intensity according to Pollock and colleagues (1998). Participants exercised on an Ergoline cycle (Ergoselect 100, Ergoline GmbH, Bitz, Germany). After a warm-up of 3 minutes at 65-70 revolutions per minute (rpm) and low workload (50-100 Watts, depending on participant's age and build) allowing them to progressively reach the predetermined intensity (60% VO_{2max}), they continued to exercise for an additional 17 minutes (i.e., 20 minutes in total). Throughout the exercise bout, HR was collected every minute and workload changes were accomplished if necessary to maintain the 57% HRR target. Two minutes after the end of the exercise session, the Vigor-Activity subscale was completed again, and finally, the TMT measures were administered (i.e., about 3 minutes post-exercise). In order to detect effects of exercise on feelings of energy, it was deemed important to reassess this variable shortly after termination of exercise, as Ekkekakis, Lind, and Vazou (2010) evidenced that exercise-induced energy increases usually return to pre-exercise levels quite quickly, within the first 10 minutes of recovery. Interaction with participants was limited to assessing pertinent research-related information. Water was provided on request during and after exercise.

Control (TV-watching) condition. Data collection occurred in the same location as the exercise condition. After completing the Vigor-Activity subscale, participants sat and watched a French TV program of 20 minutes duration ("C'est pas sorcier", French for "It's not rocket science") about sport, exercise, and health ("Practicing sport is all about physics and chemistry", first broadcast on France #3 channel on 12.11.2009). "C'est pas sorcier" is a French educational TV program in which two presenters visit different places relevant to the topic, interview specialists, and introduce questions that a third presenter ("Jamy") answers. This program was pre-screened for emotionally charged images or topics. Participants were instructed not to sleep or do any other activity while watching. As in the exercise condition, the Vigor-Activity subscale and the TMT measures were taken two minutes after the end of the intervention. Water was also available at all times.

Data analysis

First, the repeated measurements of Vigor-Activity within each condition were combined for each participant (post exercise score – pre exercise score) to produce a single value representing the difference between post-testing and pre-testing values. These difference scores are referred to as Vigor-Activity gain values in our subsequent analysis.

Exercise vs. control Vigor-Activity gain values were examined using a 2 (gender: male, female) × 2 (age group: younger, older) × 2 (condition: exercise, control) mixed ANOVA. Alpha was set at .05, and partial eta-squared was used to indicate effect size. Significant interactions revealed by the omnibus analyses of variance were further analyzed on the individual variables with *t*-tests, applying Bonferroni's corrections for multiple comparisons. Effect sizes (ES), Cohen's $d = (M_i - M_j)/SD_{pooled}$, were computed in case of significant differences in mean scores (for within-subject comparisons, we corrected for dependence among means by taking into account the correlation between the two means, Morris & DeShon, 2002).

The mediating influence of Vigor-Activity gain value on the potentially positive consequence of exercise on cognition (TMT-Part A, TMT-Part B, and TMT-Part B/Part-A) was examined using the three steps mediational procedure advocated by Kenny, Kashy, and Bolger (1998). First, the dependent variable (Y; each of the three TMT measures in the present study) was regressed onto the independent variable (X; exercise in the present study). Second, the mediating variable (M; Vigor-Activity gain value in the present study) was regressed onto the independent variable. And third, the dependent variable was regressed onto the mediating variable whilst controlling for any effects of the independent variable. This can be translated in the following equations: (1) $Y = b_0 + b_1X$; (2) $M = b_0 + b_1X$; and (3) $Y = b_0 + b_1M + b_2X$. For full mediation, the b_1 regression coefficients should be statistically different from 0 in both equations, and b_2 should *not* be statistically different from 0 in equation (3). Partial mediation is achieved when b_1 and b_2 are statistically different from 0 in equation (3).

Results

Demographic characteristics of participants

There were no differences between younger and older participants in terms of gender, $\chi^2(1) = 0.28$, $p = .598$ or education, $t(66) = -1.56$, $p = .124$ (highest duration of education: 11.45 years, $SD = 2.43$ among the older participants group vs. 12.31 years, $SD = 2.13$ for their younger counterparts).

Effects of condition, age, and gender on Vigor-Activity changes and TMT measures

Means (*M*) and standard deviations (*SD*) for Vigor-Activity scores and TMT measures (TMT-Part A, TMT-Part B, TMT-Part B/Part-A) as a function of condition, age group, and sex are presented in Table 1.

------------------------------------insert Table 1 about here--

The mixed ANOVA on Vigor-Activity gain values produced a significant age × sex × condition interaction, $F(1, 64) = 4.12$, $p = .047$, partial $\eta^2 = 0.06$. Post-hoc inspection of the group means revealed that young female participants had a significantly more positive Vigor-Activity gain value in the exercise condition ($M = +2.79$, $SD = 6.67$) than in the control condition ($M = -4.26$, $SD = 4.01$), $p < .001$, $ES = 1.26$. These effects were not found in any of the other groups where Vigor-Activity gain values remained statistically similar across experimental conditions (see Fig. 2).

------------------------------------insert Figure 2 about here---

Regarding the TMT-Part A measure, the mixed ANOVA showed a significant condition main effect, $F(1, 62) = 22.21$, $p < .001$, partial $\eta^2 = 0.26$. Post-hoc analyses revealed that male and female participants of both age groups completed this cognitive task significantly faster after the exercise condition compared to the TV-watching condition (see Table 1 for full details). An age × condition interaction was identified for participants' performance on TMT-Part B, $F(1, 62) = 9.17$, $p < .005$, partial $\eta^2 = 0.13$. Post-hoc comparisons indicated that exercise positively impacted performance in older participants (TV-watching condition: $M = 130.27$, $SD = 66.96$; exercise condition: $M = 105.70$, $SD = 53.21$, $p < .001$, $ES = -1.09$) but not in younger ones (TV-watching condition: $M = 56.42$, $SD = 18.23$; exercise condition: $M = 48.91$, $SD = 16.82$, $p = .42$, $ES = -0.37$). No age × condition × gender interaction was found.

Impact of Vigor-Activity pre-testing scores on Vigor-Activity gain values

A strong negative correlation between pre-testing scores and difference scores was observed in the exercise condition ($r = -0.54$, $p < 0.001$). Inspection of the scatterplots revealed that lower Vigor-Activity scores before exercise were associated with greater post-exercise improvements. Interestingly, the correlations were significant only in young participants. In contrast, pre-testing VA scores had no relationships with VA gain values in the TV-watching condition (correlations were nonsignificant in both participant groups, as well as for the sample taken as a whole).

Examination of the mediating role of Vigor-Activity gain values in the exercise-cognition relationships

We examined the three conditions for mediation suggested by Kenny *et al.* (1998). The first one requires that Exercise (the independent variable) predicts Cognitive Performance (the dependent variable, operationalized through the three TMT measures). This condition was satisfied for TMT-Part A ($\beta = -0.21$, $p < 0.01$), but not for the two other TMT measures. The second condition requires that Exercise predicts Gains in Vigor-Activity (the mediating variable). This condition was met ($\beta = 0.28$, $p < 0.01$). Kenny's *et al.* third condition requires that Gains in Vigor-Activity predicts Cognitive Performance (TMT-Part A, TMT-Part B, TMT-Part B/TMT-Part A) when entered together with exercise; *and* that the impact of Exercise decreases relative to when it was examined alone. Once again, this condition was satisfied for TMT-Part A, but not for the two other TMT measures. As shown in Table 2, after entering Gains in Vigor-Activity and Exercise as predictors of TMT-Part A, the relationship between Exercise and TMT-Part A became nonsignificant ($\beta = -0.15$, $p = .08$) whereas the strength of the path between Gains in Vigor-Activity and TMT-Part A remained significant ($\beta = -0.18$, $p < .05$). This shows a full mediation effect of VA gains in the relationship between exercise and raw performance on TMT-A (i.e., psychomotor speed and attention).

---------------------------------------insert Table 2 about here--

Discussion

In this study, we examined self-rated feelings of energy before and after a moderate intensity cycling session (compared to a TV control condition) in a sample of younger and older men and women. Even though Vigor-Activity may not fully reflect the construct of Positive-Activated Affect (PAA), our findings can be said to be only weakly consistent with previous literature that provided data on the effect of acute aerobic exercise on PAA. Indeed, in the present study, self-reported Vigor-Activity *did not* increase pre-to post-exercise (except for young female participants).

Specifically focusing on age, our findings agree neither with those of Focht *et al.* (2007) in which older adults demonstrated a significant decline in PAA during and after an exercise bout, nor with those recently reported by Hogan *et al.* (2013) showing on the contrary that a single bout of exercise had a beneficial effect on PAA in both young and older adults. Of course, these discrepancies with our results may be ascribed to the use of different measurement instruments: the Exercise-induced Feeling Inventory (EFI, Gauvin & Rejeski, 1993) in the study by Focht *et al.* (2007), a composite affect score deriving from an author-designed list of items in the study by Hogan *et al.* (2013), and the POMS Vigor-Activity subscale in the present one. Because these three studies were very similar regarding procedure and participants, it could be argued that the instruments employed by their authors may actually measure slightly different aspects of PAA.

As noted previously, the absence of PAA benefits after acute exercise in older participants can possibly be attributed to the likely higher prevalence of long-standing diseases characterized by increased symptoms of fatigue that would interfere with obtaining an "energy boost" from exercise. Although the presence of disease or concomitant therapy in older participants from the present sample was unlikely (it was stipulated in our informed consent form that participants had to be disease-free and not under medical treatment), it cannot be excluded since it was not directly assessed as part of the study. Regardless, the finding that older participants report no significant gain in vigor following exercise might be relevant for the refinement of intervention programs designed to improve feelings of energy and alertness, in the domain of drowsy-driving prevention, for instance. In Europe, sleepiness is a major cause of fatal traffic-road accidents, representing 20% of fatal crashes (INSV, 2014). As identified by Anund, Kecklund, Peters, & Arkestedt (2008), the most common countermeasure used by drivers against sleepiness is to stop to take a walk (54%). Exercising also appeared to be in the top 10 (28%). Based on our results which demonstrate that an acute bout of moderate-intensity exercise does not necessarily result in immediate increased energy levels, the efficacy of such countermeasures could be questioned.

With regard to gender, our results are fairly consistent with those from studies that found higher exercise-induced mood benefits in women compared to men (Hansen *et al.*, 1997; Rocheleau *et al.*, 2004). In line with the explanation we proposed earlier, one reason why young women exhibited more positive Vigor-Activity changes in our exercise condition might be that they reported lower pre-exercise levels of Vigor-Activity than participants in the other groups. Nevertheless, the present findings suggest that different processes may be operating for young women than for the other groups. As suggested in the domain of exercise physiology (e.g., Kaciuba-Uscilko & Grucza, 2000), the changing rate of sex hormone release during the menstrual cycle may modify the thermoregulatory response to exercise. For instance, results from men and women exercising at the same relative intensity in a thermoneutral environment revealed that women at a specific stage of their menstrual cycle (i.e., the luteal phase) had lower increases in rectal temperature than men (Grucza, 1990). Although a number of studies conducted during the 80s and the 90s resulted in very little support for the thermogenic hypothesis (e.g., Youngstedt, Dishman, Cureton, & Peacock, 1993), recent investigations have suggested that differences in body temperature during exercise are associated with different changes in affective responses during and immediately after exercising (Magnan, Kwan, & Bryan, 2013; Legrand, Bertucci, & Arfaoui, 2014). To the best of our knowledge, no research specifically examining the link between gender differences in thermoregulation and their association with mood changes following exercise has yet been published; so it would be an interesting direction for future research.

Taken as a whole, our data generally supported the view that participants reporting lower pre-exercise feelings of energy would improve more post-exercise than those with higher pre-exercise energy levels (r = -0,54, p < .001). Though this finding may be an artifact due to regression to the mean, it has previously been reported (see Blanchard, Rodgers, Courneya, & Spence, 2002; Reed, Berg, Latin, & La Voie, 1998). Interestingly, when our data were analyzed by gender and age, this moderating effect of pre-exercise Vigor-Activity level was not found in older participants. The precise mechanism of this age-associated difference remains to be elucidated.

Another important feature of our study is that it presents initial data supporting the hypothesis by Spirduso *et al.* (2008), according to which, change in levels of energy is a mediator by which physical activity exerts beneficial effects on cognition. More specifically, gains in Vigor-Activity fully mediated the relationship between exercise and TMT-Part A performance. Unfortunately, this was not replicated in the other TMT measures (TMT-Part B, TMT Part B/Part A) involving more complex mental processes (mental flexibility, working memory). This new finding will need to be verified in future studies by including other proposed indirect paths that exercise might take in positively affecting cognition (e.g., sleep, depression). Indeed, studying how exercise can affect individual resources that can in turn affect cognition will increase understanding of the facilitative mechanisms of exercise on cognition as individuals age.

In interpreting the findings reported here, two limitations should be acknowledged. First, we recruited an ethnically homogeneous sample of healthy individuals. Therefore, replication of this study in more diverse sample (e.g., individuals with chronic diseases, minority populations) is necessary to determine the extent to which our results are representative of other persons within the community. A second important limitation is that feelings of energy were only assessed at 2 time points, just before and 2 minutes after each intervention (exercise, TV-watching). Obtaining additional in-task and post-exercise assessments would allow capture of other potentially meaningful Vigor-Activity changes and should be incorporated in future research. However, prior research has already shown that participation in short sessions of moderate-intensity aerobic exercise (15 min of walking at about 65% of age-predicted maximal heart rate) significantly increases self-reported levels of energy in healthy adults during exercise, returning quickly (i.e., in the first 5-10 minutes of recovery) to little above pre-exercise levels (Ekkekakis, Backhouse, Gray, & Lind, 2008).

In conclusion, although previous work has shown that an acute bout of aerobic exercise generally results in feelings of energy, very little attention has been directed at determining whether this effect is similarly present across different age groups and for participants of both gender. The present study helps clarify that only young female participants report a statistically significant improved Vigor-Activity score following exercise compared to a TV-watching control condition. The lack of an increase in Vigor-Activity among older adults may contribute to the difficulties experienced by these people in maintaining a regular exercise program. In addition, the present study shows initial evidence for the mediating role of changes in feelings of energy in the relationship between exercise and cognition.

References

American College of Sports Medicine. (2010). *ACSM's guidelines for exercise testing and prescription (8th ed.)*. New York: Lippincott, Williams & Wilkins.

Anund, A., Kecklund, G., Peters, B., & Akerstedt, T. (2008). Driver sleepiness and individual differences in preferences for countermeasures. *Journal of Sleep Research, 17(1)*, 16-22. doi: 10.1111/j.1365-2869.2008.00633.x

Bixby, W. R., & Lochbaum, M. R. (2006). Affect responses to acute bouts of aerobic exercise in fit and unfit participants: An examination of opponent-process theory. *Journal of Sport Behavior, 29(2),* 111-125.

Blanchard, C. M., Rodgers, W. M., Courneya, K. S., & Spence, J. C. (2002). Moderators of the exercise/feeling-state relationship: The influence of self-efficacy, baseline, and in-task feeling states at moderate- and high-intensity exercise. *Journal of Applied Sport Psychology, 32(7),* 1379-1395.

Buckworth, J., Dishman, R. K., O'Connor, P. J., & Tomporowski, P. D. (2013). *Exercise psychology*, 2nd ed. Champaign, Ill: Human Kinetics.

Cayrou, S., Dickes, P., Gauvain-Piquard, A., Dolbeault, S., Callahan, S., & Roge, B. (2000). Validation de la traduction française du POMS (Profile of Mood States) [Validation of the French translation of the Profile of Mood States]. *Psychologie & Psychométrie, 21*, 5-22.

Ekkekakis, P., & Backhouse, S. H. (2014). Physical activity and feeling good. In A. Papaioannou & D. Hackfort (Eds.), *Routledge companion to sport and exercise psychology: Global perspectives and fundamental concepts* (pp. 687-704). New York: Routledge.

Ekkekakis, P., Backhouse, S. H., Gray, C., & Lind, E. (2008). Walking is popular among adults but is it pleasant? A framework for clarifying the link between walking and affect as illustrated in two studies. *Psychology of Sport & Exercise, 9(3)*, 246-264.

Ekkekakis, P., Lind, E., & Vazou, S. (2010). Affective responses to increasing levels of exercise intensity in normal-weight, overweight, and obese middle-aged women. *Obesity*, 18(1), 79-85.

Ekkekakis, P., Parfitt, G., & Petruzzello, S.J. (2011). The pleasure and displeasure people feel when they exercise at different intensities: Decennial update and progress towards a tripartite rationale for exercise intensity prescription. *Sports Medicine, 41(8)*, 641-671.

Focht, B. C., Knapp, D. J., Gavin, T. P., Raedeke, T. D., & Hickner, R. C. (2007). Affective and self-efficacy responses to acute aerobic exercise in sedentary older and younger adults. *Journal of Aging & Physical Activity, 15(2),* 123-138.

Gauvin, L., & Rejeski, W. J. (1993). The Exercise-Induced Feeling Inventory: Development and initial validation. *Journal of Sport & Exercise Psychology, 15(4)*, 403-423.

Grucza, R. (1990). Efficiency of thermoregulatory system in man under endogeneous and exogeneous heat loads. *Acta Physiologica Polonica, 41(4-6),* 123-145.

Hamer, M., Endrighi, R., & Poole, L. (2012). Physical activity, stress reduction, and mood: insight into immunological mechanisms. *Psychoneuroimmunology: Methods in Molecular Biology, 934*, 89-102.

Hansen, C. J., Moses, K., & Gardner, C. (1997). The effects of time-incremented running on mood states of college athletes. *Psi Chi Journal of Undergraduate Research, 2,* 133-189.

Hoffman, M. D. , & Hoffman, D. R. (2008). Exercisers achieve greater acute exercise-induced mood enhancement than nonexercisers. *Archives of Physical Medicine & Rehabilitation, 89(2),* 358-363. http://dx.doi.org/10.1016/j.apmr.2007.09.026

Hogan, C. L., Mata, J., & Carstensen, L. L. (2013). Exercise holds immediate benefits for affect and cognition in younger and older adults. *Psychology & Aging, 28(2),* 587-594. doi:10.1037/a0032634.

Institut National du Sommeil et de la Vigilance. (2013). *La somnolence au volant : livre blanc [Sleepiness at the wheel: White paper]*. Retrieved from http://www.autoroutes.fr/FCKeditor/UserFiles/File/Livre_Blanc_Somno_BILINGUE.pdf

Kaciuba-Uscilko, H., & Grucza, R. (2001). Gender differences in thermoregulation. *Current Opinion in Clinical Nutrition & Metabolic Care, 4(6),* 533-536.

Karvonen, M. J., Kentala, E., & Mustala, O. (1957). The effects of training on heart rate: A longitudinal study. *Annales Medicinae Experimentalis et Biologiae Fenniae, 35(3),* 307-315.

Kenny, D. A., Kashy, D., & Bolger, N. (1998). Data analysis in social psychology. In D. Gilbert, S. Fiske, & G. Lindzey (Eds.), *Handbook of social psychology* (4th ed., pp. 233-265). New York: McGraw-Hill.

Legrand, F. D., Bertucci, W. M. & Arfaoui, A. (2014). Relationships between facial temperature changes, end-exercise affect, and during-exercise changes in affect: A preliminary study. *European Journal of Sport Sciences.* DOI: 10.1080/17461391.2014.948077.

Magnan, R. E., Kwan, B. M., & Bryan, A. D. (2013). Effects of current physical activity on affective response to exercise: Physical and social-cognitive mechanisms. *Psychology & Health, 28,* 418-433. http://dx.doi.org/10.1080/08870446.2012.733704

McNair, D. M., Lorr, M. & Droppleman, L. F. (1992). *The Profile of Mood States*. San Diego: Educational and Industrial Testing Service.

Merns, K. (1995). Mood and self-esteem enhancement in different exercise modes. *Dissertation Abstracts International: Section B: The Sciences and Engineering, 55,* 5571.

Mogil, J. S. (1999). The genetic mediation of individual differences in sensitivity to pain and its inhibition. *Proceedings of the National Academy of Sciences, 96,* 7744-7751.

Morris, S. B., & DeShon, R. P. (2002). Combining effect size estimates in meta-analysis with repeated measures and independent-group designs. *Psychological Methods, 7*, 105-125.

Netz, Y., Wu, M. J., Becker, B. J., & Tenenbaum, G. (2005). Physical activity and psychological well-being in advanced age: A meta-analysis of intervention studies. *Psychology & Aging, 20(2),* 272-284.

Oosterman, J. M., Vogels, R. L. C., Van Harten, B., Gouw, A. A., Poggesi, A., Scheltens, P., Kessels, R. P. C, & Scherder, E. J. A. (2010). Assessing mental flexibility: neuroanatomical and neuropsychological correlates of the Trial Making Test in elderly people. *The Clinical Neuropsychologist, 24,* 203-219.

Pollock, M. L., Gaesser, G. A., Butcher, J. D., Despres, J. P., Dishman, R. K., Franklin, B. A., & Garber, C. E. (1998). The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. *Medicine & Science in Sports & Exercise, 30(6)*, 975-991.

Puetz, T. W. (2006). Physical activity and feelings of energy and fatigue: epidemiological evidence. *Sports Medicine, 36(9)*, 767-780.

Reed, J., Berg, K. E., Latin, R. W., & La Voie, J. P. (1998). Affective responses of physically active and sedentary individuals during and after moderate aerobic exercise. *Journal of Sports Medicine & Physical Fitness, 38(3),* 272-278.

Reed, J., & Ones, D. S. (2006). The effects of acute aerobic exercise on positive activated affect: A meta analysis. *Psychology of Sport & Exercise, 7(5),* 477-514.

Reitan, R. M., & Wolfson, D. (1985). *The Halstead–Reitan Neuropsycholgical Test Battery: Therapy and clinical interpretation*. Tucson, AZ: Neuropsychological Press.

Rocheleau, C. A., Webster, G. D., Bryan, A., & Frazier, J. (2004). Moderators of the relationship between exercise and mood changes: Gender, exertion level, and workout duration. *Psychology & Health, 19(4),* 491-506.

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality & Social Psychology, 39(6)*, 1161-1178.

Spirduso, W. W., Poon, L. W., & Chodzko-Zajko, W. (2008). *Exercise and its mediating effects on cognition. Aging, Exercise, and Cognition Series, volume 2*. Champaign, Ill: Human Kinetics.

Swain, D. P., & Leutholtz, B. C. (1997). Heart rate reserve is equivalent to %$VO_{2reserve}$, not to % VO_{2max}. *Medicine & Science in Sports & Exercise, 29(3),* 410-414.

Swain, D. P., Leutholtz, B. C., King, M. K., Haas, L. A., & Branch, J. D. (1998). Relationship between % heart rate reserve and % $VO_{2reserve}$ in treadmill exercise. *Medicine & Science in Sports & Exercise, 30(2),* 318-321.

Van Landuyt, L.M., Ekkekakis, P., Hall, E.E., & Petruzzello, S.J. (2000). Throwing the mountains into the lakes: On the perils of nomothetic conceptions of the exercise-affect relationship. *Journal of Sport & Exercise Psychology, 22(2),* 208-234.

Youngstedt, S. D., Dishman, R. K., Cureton, K. J., & Peacock, L. J. (1993). Does body temperature mediate anxiolytic effects of acute exercise ? *Journal of Applied Physiology, 74*, 825-831.