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THE COMPARATIVE EFFECTS OF EXERCISE AND NEUROSTIMULATION ON COLLEGE STUDENTS' EMOTIONAL WELL-BEING

Shaine Henert[1i],
Chris Hill[2],
Benjamin Connors[3],
Juan Navarro[3],
Grace Louis[4]
[1]PhD, EP-C,
Department of Kinesiology & Physical Education,
Northern Illinois University,
Dekalb, IL 60115, USA
[2]PhD,
School of Kinesiology,
Louisiana State University,
Baton Rouge, LA 70803, USA
[3]MSEd,
Department of Kinesiology & Physical Education,
Northern Illinois University,
Dekalb, IL 60115, USA
[4]MS,
Department of Kinesiology & Physical Education,
Northern Illinois University,
Dekalb, IL 60115, USA

Abstract:
Concern for college students' mental health has grown recently as rates of anxiety, depression, and suicidal ideation have risen. Although exercise has been shown to improve one's mental health, few young adults engage in sufficient regular exercise to achieve these benefits. Identifying innovative strategies to maintain emotional well-being would help support the mental health of young adults. Therefore, the objectives of this study were to examine the comparative effects of acute moderate-to-vigorous physical activity (MVPA) and transdermal nerve stimulation (TNS) on one's perceptions of emotional well-being. Twenty-two, healthy, physically active, college-age individuals participated in the study. A within-subjects crossover design was used to compare participants' ratings of positive and negative affect using the PANAS. Ratings of positive affect were significantly higher in the exercise compared to the control condition, but only

[i] Correspondence: email shenert@niu.edu

slightly higher than the TNS condition. There were no significant differences in ratings of negative affect. This supports previous research that acute exercise promotes emotional well-being. It also provides preliminary support for the innovative use of neurostimulation to enhance one's emotional well-being. More research is needed to better understand the efficacy and practicality of using neurostimulation as a complement to exercise to support college students' emotional well-being.

Keywords: college students, affect, emotional well-being, exercise, neurostimulation

1. Introduction

The emotional well-being of college students has gained significant attention, especially recently due to the COVID-19 pandemic (Mack *et al.*, 2021). Emotional well-being involves experiencing more positive affect than negative affect in one's life (Diener *et al.*, 1985). According to Ekkekakis (2008), affect covers a broad range of feelings that people can experience and encompasses both emotions (e.g., anger, happiness) and moods (i.e., generally positive or negative). Generally speaking, mood disorders, like depression, often coexist with anxiety disorders and involve an unhealthy balance of positive and negative affect (i.e., negative emotional well-being). Therefore, maintaining one's positive emotional well-being reduces one's chances of experiencing depression and anxiety.

Short bouts of acute moderate-to-vigorous exercise have been shown to improve one's positive affective states (Daley & Welch, 2004; Ekkekakis *et al.*, 2000; Ensari *et al.*, 2015; Liao *et al.*, 2015; Reed, 2013; Reed & Henert; 2009; Reed & Ones, 2006), but the findings regarding negative affective states are inconclusive (Liao *et al.*, 2015). In addition, exercise has been shown to help one manage their levels of depression and anxiety (deMoor *et al.*, 2006; Dishman *et al.*, 2012; Harvey *et al.*, 2018; Jerstad *et al.*, 2010; McDowell *et al.*, 2018; Motl *et al.*, 2004; Pinto-Pereira *et al.*, 2014; Stonerock *et al.*, 2015; U.S. Department of Health and Human Services, 2018). Although exercise has been shown to improve one's positive affective states, few young adults engage in sufficient regular exercise to achieve these benefits (Centers for Disease Control & Prevention, 2022). Identifying innovative strategies to maintain emotional well-being would help support the mental health of young adults.

Transdermal neurostimulation (TNS) is the application of an electric current to skin over trigeminal afferents, which propagate toward brain areas that are related to stress and anxiety (e.g., amygdala and the frontal lobe) (Garcia-Rill *et al.*, 2015; Shiozawa *et al.*, 2014). TNS has shown promise in improving one's symptoms of anxiety and mental stress (Monaco *et al.*, 2017) and has demonstrated clinical relevance in treating individuals with PTSD (Cook *et al.*, 2016; Koek *et al.*, 2019) and major depressive disorder (Cook *et al.*, 2013). However, little is known about its effect on one's affective state. More research focusing on the comparative effects of acute exercise and transdermal neurostimulation on affective states is needed to find more innovative ways to help young adults achieve emotional well-being.

The purpose of this study was to examine the comparative effects of acute moderate-to-vigorous physical activity (MVPA) and transdermal nerve stimulation (TNS) on one's perceptions of positive and negative affect (i.e., emotional well-being). Based on previous research, we hypothesized that the acute exercise condition would result in more positive affect than both the TNS and control conditions. Based on the inconclusive findings regarding the effect of acute exercise on negative affect and the limited research on the effect of neurostimulation on affect, both positive and negative, our investigation here was more exploratory in nature.

2. Materials and Methods

2.1 Participants

Twenty-two, healthy, college-age individuals (mean age = 22.23 ± 2.02 years) participated in the study.

2.2 Measures

Positive and negative affect were measured using the Positive and Negative Affect Schedule (PANAS; Watson *et al.*, 1988). The PANAS is a twenty-item scale that assesses both positive and negative affect by rating positive and negative emotions felt in the past week on a one to five Likert scale. The points of the scale are labeled as: Very slightly or not at all (1), A little (2), Moderately (3), Quite a bit (4), and Very much (5). Scores range from 10-50 for both the positive and negative affect subscales, with lower scores representing lower levels of positive/negative affect and higher scores representing higher levels of positive/negative affect (Watson *et al.*, 1988). The PANAS has been used frequently with non-clinical populations and displays very good internal reliability, with Cronbach alpha coefficients of 0.88 for the Positive Affect Scale and 0.85 for the Negative Affect Scale (Crawford & Henry, 2004; Watson *et al.*, 1988). In the current study, internal consistency values for the Positive and Negative Affect Scales across the three experimental conditions were .89 and .97 (exercise), .91 and .85 (TNS), and .96 and .92 (control), respectively, indicating good to excellent reliability.

2.3 Procedures

This study received university Institutional Review Board approval (HS21-0417) and the consent of the participants. We used a within-subjects crossover design as each participant completed three randomized, counterbalanced conditions – 1) submaximal treadmill exercise at 60-90%HR_{max}, 2) non-invasive transdermal stimulation of the right trigeminal nerve, and 3) sitting quietly (control) over three separate sessions in the same motor behavior laboratory. Each session consisted of the following sequence: first administration of the PANAS, first viewing of randomized images from the Open Affective Standardized Image Set (OASIS; Kurdi *et al.*, 2016), second administration of

PANAS, intervention condition (exercise, TNS, or control), second viewing of OASIS images, and final administration of the PANAS. Each session was separated by 48 hours and was performed at the same time of day for each participant ($\pm$2 hours).

The exercise condition (EX) was created based on the findings of previous research focusing on the effect of exercise on psychological factors (Ensari *et al.*, 2015; Hansen *et al.*, 2001; Petruzzello *et al.*, 1991; Reed & Henert, 2009). It included a brief warm-up, a 12-minute about of continuous walking/running on a treadmill with speed adjusted to maintain 60-90%HR_{max}, and a cool-down period. Moderate-to-vigorous intensity levels for each participant were calculated using the age-predicted maximum heart rate (HR_{max}) formula – i.e., 220-age (Fox *et al.*, 1971). Exercise heart rates for the exercise condition were established by multiplying HRmax by 60-90%, following the American College of Sports Medicine guidelines (Liguori, 2021). Heart rate and perceived exertion were assessed each minute during the exercise condition using a Polar heart monitor and the Rating of Perceived Exertion (RPE) scale (Borg, 1998). The TNS condition involved placing a commercially produced neurostimulation patch (i.e., Thync FeelZing Extra Strength Energy Patch) behind the participant's right ear on the mastoid bone. This area contains important nerve connections to the sympathetic nervous system (i.e., greater auricular and lesser occipital nerves) and parasympathetic nervous system (i.e., the vagus nerve). Once activated, the patch emits seven minutes of high frequency, high amplitude electrical stimulation via the cranial nerves of the autonomic nervous system (ANS). It is designed to create an optimal balance of the ANS, resulting in an immediate calm, energized state. The control condition involved sitting quietly for 15 minutes (Quiet sitting (QS)).

Twice during each of the conditions, participants viewed a counterbalanced, standardized slide show with twenty-four randomized pictures from the Open Affective Standardized Image Set (OASIS; Kurdi *et al.*, 2016), using the PsychoPy program (Pierce, 2007). The OASIS is an open-access online stimulus set containing 900 color images depicting an extensive variety of themes (including humans, animals, objects, and scenes). The twenty-four picture slides show consisted of 8 random pictures from each valance category of pleasant, unpleasant, and neutral defined by OASIS (Crawford & Henry, 2004). Following the procedures of Crabbe *et al.* (2007), pictures from OASIS were viewed before and after the assigned counterbalance randomly assigned intervention (EX, TNS, QS). Having participants view the images before and after each condition allowed us to elicit positive and negative affective responses within testing and assess acute changes to both types of effects related to the interventions.

2.4 Data analysis

Separate 3 (condition: exercise, TNS, sitting quietly) x 3 (time: 1, 2, 3) repeated measures ANOVAs were performed to determine the comparative effects of different treatments over time on one's perceptions of positive and negative affect (i.e., emotional well-being). All analysis was conducted in SPSS v26 (IBM Corp., Armonk, NY, USA) with an alpha level of 0.05.

3. Results

Overall average participant heart rates and rates of perceived exertion during the exercise condition supported that they maintained at least moderate intensity levels – mean HR = 139.63 ± 15.51 bpm and mean RPE = 12.26 ± 1.60. Descriptive statistics of the positive and negative PANAS scores are provided in Table 1.

Table 1: Means and standard deviations for PANAS subscale scores

	Positive Affect		**Negative Affect**	
	Mean	***SD***	***Mean***	***SD***
Time 1				
Exercise	32.86	8.10	13.59	4.80
TNS	34.00	6.87	12.95	4.48
Quiet sitting (control)	33.18	10.32	13.32	4.84
Time 2				
Exercise	31.00	7.20	12.91	4.28
TNS	32.09	8.36	13.45	4.73
Quiet sitting (control)	29.41	10.45	12.64	3.90
Time 3				
Exercise	32.55	7.16	12.14	3.83
TNS	31.82	9.40	13.45	5.76
Quiet sitting (control)	27.86	10.08	12.50	4.13

All assumptions to perform a 2-way repeated measures ANOVA were met for the PANAS, p was set at <.05. There was a statistically significant interaction between condition and time on perceptions of *positive* affect, $F(4, 84) = 3.26$, $p = .015$, partial $\eta^2 = .134$. Simple main effect analyses revealed that there were only significant differences in *positive* affect between the conditions during the follow-up trial (i.e., time point 3), $F(2, 42) = 5.27$, $p = .009$, partial $\eta^2 = .201$. Bonferroni post hoc analyses revealed that perceptions of *positive* affect were significantly higher in the exercise condition (32.55 ± 7.16) compared to the control condition (27.86 ± 10.08), a mean difference of 4.68 (95% CI, .61 to 8.76), $p = .021$. Interestingly, analyses revealed that perceptions of *positive* affect were not significantly higher in the exercise condition compared to the TNS condition (31.82 ± 9.40), a mean difference of only .73 (95% CI, -3.20 to 4.65), $p > .05$.

There was no statistically significant two-way interaction between treatment and time for *negative* affect, $F(4, 84) = 1.59$, $p = .203$. The main effects for condition and time also revealed no significant differences in *negative* affect - $F(2, 42) = .199$, $p = .820$ and $F(2, 42) = .870$, $p = .426$, respectively.

4. Discussion

The purpose of the study was to examine the comparative effects of acute MVPA to transdermal neurostimulation on one's perceptions of positive and negative affect (i.e., emotional well-being). Our hypothesis that acute MVPA would result in a more positive affect than both the transdermal neurostimulation and control conditions was supported. Our finding that exercise contributes to more positive affect supports previous research (Daley & Welch, 2004; Ekkekakis *et al.*, 2000; Ensari *et al.*, 2015; Liao *et al.*, 2015; Reed, 2013; Reed & Henert; 2009; Reed & Ones, 2006). The results of our exploratory analysis that exercise did not result in significant reductions in negative affect also support previous research (Liao *et al.*, 2015), although ratings did decrease somewhat after exercise.

Interestingly, we did find TNS to be just slightly less effective than exercise and nearly significantly more effective than the control condition in supporting one's positive affect. This would support the use of TNS as an innovative strategy to enhance one's positive affective states when one is unable to meet the recommended physical activity levels needed to maintain emotional well-being. Moreover, this also suggests that exercise may stimulate similar neural pathways to that of TNS, however, this is speculative and would require future research. Transdermal neurostimulation devices, like the one used in the current study, are commercially available and are very easy and convenient to use. Future research is needed to better understand the potential of TNS in supporting young adults' mental health and well-being.

4.1 Strengths and Limitations

A key strength of this study is the use of a within-subjects crossover design, which has a number of advantages. First, each participant serves as their own control, reducing inter-individual variability and the influence of covariates (Jones & Kenward, 2015). Second, a crossover design maintains high statistical power, supporting confidence in our results, even with a relatively small sample size (Chow & Liu, 2009; Senn, 2002). However, our study is not without its limitations. There were a limited number of female participants in the study (N = 3), so future research should attempt to recruit equitable numbers of males and females. The participants in this study were active, based on their self-reports, which may have diminished the effects that exercise and neurostimulation had on their perceptions of positive and negative affect. Future research should consider recruiting participants of varying activity levels to determine the effect of similar interventions on the emotional well-being of less active individuals.

5. Conclusion

Maintaining emotional well-being reduces the risk of anxiety and depression interfering with the health and well-being of college students, supporting their academic success. The results of this study support previous findings that regular physical activity promotes positive mental health. In addition, innovative approaches like neurostimulation can support the mental health of college students. College health professionals can use this information to provide mental health education and support for their students.

Conflict of interest disclosure
The authors have no conflicts of interest to report.

About the Author(s)

Shaine Henert (PhD) is an Associate Professor in the Kinesiology & Physical Education Department at Northern Illinois University. His research interests include the effect of psychological skills training on performance enhancement, the psychology of athletic injury and rehabilitation, and exercise behavior and adherence.

Chris Hill (PhD) is an Assistant Professor in the School of Kinesiology at Louisiana State University. His research interests include motor neuroscience, reinforcement-based motor learning, human gait and balance, and electroencephalography.

Benjamin Connors, MSEd, is a former graduate student in the Kinesiology & Physical Education Department at Northern Illinois University.

Juan Navarro, MSEd, is a former graduate student in the Kinesiology & Physical Education Department at Northern Illinois University.

Grace Louis, MS, is a doctoral student in the Kinesiology & Physical Education Department at Northern Illinois University. Her research interests include the mental health of college student athletes.

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