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ARTICLE

The Effects of Accumulated Short Bouts of Mobile-Based Physical Activity Programs on Depression, Perceived Stress, and Negative Affectivity among College Students in South Korea: Quasi-Experimental Study

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ABSTRACT

Regular physical activity (PA) is known to enhance multifaceted health benefits, including both physical and mental health. However, traditional in-person physical activity programs have drawbacks, including time constraints for busy people. Although evidence suggests positive impacts on mental health through mobile-based physical activity, effects of accumulated short bouts of physical activity using mobile devices are unexplored. Thus, this study aims to investigate these effects, focusing on depression, perceived stress, and negative affectivity among South Korean college students. Forty-six healthy college students were divided into the accumulated group (n = 23, female = 47.8%) and control group (n = 23, female = 47.6%). The accumulated group engaged in mobile-based physical activity, following guidelines to accumulate a minimum of two times per day and three times a week. Sessions were divided into short bouts, ensuing each bout lasted at least 10 min. The control group did not engage in any specific physical activity. The data analysis involved comparing the scores of the intervention and control groups using several statistical techniques, such as independent sample *t*-test, paired sample *t*-tests, and 2 (time) × 2 (group) repeated measures analysis of variance. The demographic characteristics at the pre-test showed no statistically significant differences between the groups. The accumulated group had significant decreases in depression (t_{40} = 2.59, p = 0.013, Cohen's D = 0.84) and perceived stress (t_{40} = 2.06, p = 0.046, Cohen's D = 0.56) from the pre- to post-test. The control group exhibited no statistically significant differences in any variables. Furthermore, there were significant effects of time on depression scores ($F_{1,\ 36}$ = 4.77, p = 0.036, η_p^2 = 0.12) while significant interaction effects were also observed for depression ($F_{1,\ 36}$ = 6.59, p = 0.015, η_p^2 = 0.16). This study offers informative insights into the potential advantages of mobile-based physical activity programs with accumulated periods for enhancing mental health, specifically in relation to depression. This study illuminates the current ongoing discussions on efficient approaches to encourage mobile-based physical activity and improve mental well-being, addressing various lifestyles and busy schedules.

KEYWORDS

Depressive symptoms; mental health; mobile intervention; short term exercise; stress

Introduction

In the 2020 Organization for Economic Co-operation and Development (OECD) survey on depression prevalence among countries, South Korea recorded the highest rate of depression prevalence at 36.8%. That is, approximately 4 out of 10 individuals experience depression or feelings of sadness, highlighting the seriousness of the situation [1]. In fact, the number of patients diagnosed with depression in South Korea has reached nearly 1.02 million. Among them, the number of depression patients in their 20s was the highest, with 179,870 individuals (16.8%) [2]. Comparing the years 2013 and 2018, the increase in the diagnosis of depression among individuals in their 20s showed the highest growth rate among all age groups, at 93.2% [3]. Therefore, there is an urgent need to identify the potential remedies for depressive symptoms for young adults in South Korea.

Regular physical activity (PA) offers a diverse range of health benefits. Physical health improves cardiovascular endurance, lowers the likelihood of heart ailments, and aids in weight control by burning calories and regulating the metabolism. Moreover, it enhances muscle flexibility, hence aiding in the prevention of injuries and promoting improved bone density [4,5]. Furthermore, PA plays a crucial role in promoting mental health by reducing stress, increasing the release of endorphins to regulate mood, enhancing sleep quality, and supporting cognitive processes such as memory and focus. Indeed, PA has been found to mitigate mental disorders such as depression, stress, and anxiety [6–10]. In general, participating in regular physical activity not only increases lifespan and prevents chronic conditions, such as diabetes and some types of cancer, but also enhances immune system function, leading to a higher quality of life. Thus, the significance of incorporating and encouraging physical activity into daily routines is emphasized based on these comprehensive advantages [11].

Despite the benefits of engaging in PA, traditional in-person PA programs face limitations in terms of participation owing to the prevalent lack of time among individuals [12,13]. In fact, the structured nature of traditional programs, such as scheduled fitness classes or gymnasium sessions, often requires a significant time commitment, creating a barrier for those with busy schedules. Additionally, commuting to and from fitness centers or class locations, changing clothes, and taking showers add to the overall time investment, making it less feasible for individuals with tight schedules. The perception that engaging in such activities requires a substantial amount of time can be discouraging, leading many people to forego PA. Considering these challenges, it is essential to offer alternative options that are more adaptable.

One of the potential solutions may include utilizing technology for mobile-based PA programs [14]. In fact, there are numerous benefits to engaging in PA at home using mobile devices. First, mobile-based PA program provides flexible and convenient options and remove time limitations as it allows individuals to freely participate in PA according to their own availability and energy level compared to longer and continuous sessions [15,16]. Further, mobile-based PA improves the ease of access and convenience of PA at home, which promotes regularity and compliance with PA routines. This contributes to long-term health and overall wellbeing, as reported by Firth et al. [17]. Indeed, ample evidence has demonstrated that mobile-based PA programs have positive impacts on mental health issues such as depression, stress, anxiety, and quality of life among participants. For example, Kim et al. [14] found the significant effects of mobile phone-based PA programs on depression and perceived stress among adults. Furthermore, Vandelanotte et al. [18] investigated the effects of a three-month web-based intervention customized to individuals' needs on various mental health outcomes, including depression, anxiety, stress, and quality of life. Among the 501 participants, the intervention group showed significant decreases in depression, anxiety, and stress at both three and nine months compared to their baseline levels. These results indicated that mobile-based PA program can promote positive outcomes in terms of reducing depression and perceived stress.

In addition to the mobile-based PA program, prioritizing shorter and more time-efficient PA routines may provide a feasible option for busy people. The rationale behind this is that it aligns with their busy schedules and minimizes barriers related to time constraints [19]. However, although ample evidence suggests that mobile-based PA has a positive impact on individual mental well-being, to the best of our knowledge, no study has integrated the principles of accumulated short bouts of PA into mobile device contexts, and it remains unclear whether such practices result in the same positive effects on mental health. In fact, the majority of research on the effects of accumulated short bouts of PA has typically focused on various physical health indicators of cardiovascular risks [20,21], weight and obesity indices [22]; and fitness indicators [23]. For example, Eguchi et al. [20] categorized participants into two physical activity groups: a long-bout group, which engaged in a single 30-min session per day for three days per week, and an accumulated short-bout group, which participated in three 10-min sessions per day for three days per week. The accumulated group experienced a substantial increase in VO_2max after 10 weeks. The implementation of physical activity programs resulted in a considerable decrease in oxidative stress, with no discernible distinction between the accumulated and continuous groups. In reference to psychological outcomes, previous literature on walking has demonstrated the mixed outcomes. Osei-Tutu et al. [24] found that engaging in accumulating 30-min of walking in three 10-min bouts was not sufficient to significantly reduce the feelings of tension and anxiety over eight weeks. On the other hand, Murphy et al. [25] found that engaging in three brief 10-min sessions of brisk walking was equally effective as a single continuous session of equal duration in reducing feelings of tension and anxiety.

The lack of studies on the effects of accumulated PA and the mixed results deserves attentions because it prevents a thorough understanding of the best methods for using mobile-based platforms to improve mental well-being. It is crucial to bridge this divide and create customized and efficient PA interventions that consider individuals' limited

time and personal preferences. We believe this endeavor will contribute to progress in both mobile-based physical activity programs and mental health promotion.

Taken together, this study aimed to investigate the effects of mobile-based PA programs delivered in the form of accumulated bouts on mental health indicators, including depression, perceived stress, and negative affectivity among healthy college students in South Korea. By identifying the significant implications associated with the adoption of accumulated bouts of PA programs, our objective was to offer alternative avenues, particularly for individuals with busy schedules and reservations about attending fitness gyms.

Methods

Participants

The participants of this study were undergraduate students attending a university in Gyeonggi Province, South Korea. We recruited participants through various online and offline channels, including online advertisement, class announcements, flyers around university campus, and word of mouth. The recruitment process specifically focused on the participants who expressed a voluntary interest in this study. To ensure the quality of this research, participants must meet the following criteria: they must be in optimal physical condition and currently enrolled as full-time college students, aged between 18 and 30 years. Prior to enrollment, it was essential to have a firm commitment to complete the eight-week study period and to possess a high level of competency in the language of study. Furthermore, participants required both online and offline accessibility along with proficiency in utilizing a smartphone and internet. Finally, participants who voluntarily expressed interest in participating in the research and met the eligibility criteria were selected.

Fig. 1 displays the diagram adhering to the Consolidated Standards of Reporting Trials, outlining the flow of participants throughout the study. Consequently, 49 individuals were recruited, with five excluded before the pre-test owing to unavailability or refusal to undergo testing. The allocation of participants to the respective groups was primarily based on practical considerations, such as availability. Initially, individuals who could commit to an 8-week accumulated PA protocols were first selected and assigned to the accumulative group. From the original pool of 44 participants, 23 were assigned to the intervention group, and the remaining (21 individuals) were assigned to the control group. The comprehensive demographic information of the participants is presented in Table 1.

Following the interventions, four participants in the intervention group dropped out because they refused to undergo testing and hospitalization. In the control group, two participants dropped out because they did not complete the post-test. Remarkably, 82.60% (19 out of 23) of the participants in the intervention group and 90.40% (19 out of 21) in the control group completed the post-test. Therefore, 38 participants were included in the final analysis. G* Power 3 [26] was used to determine the sample size. To guarantee accuracy, the power of the test was set at 95% with a significance level of 0.01. The effect size (d) was determined to be 0.05 on the basis of the results obtained in a prior investigation [14]. Additionally, the attrition rate observed in computer-based psychological treatment (57%) [27] was added to the calculation. Consequently, the total number of participants was 22. Therefore, the inclusion of 44 participants was expected to yield adequate statistical power.

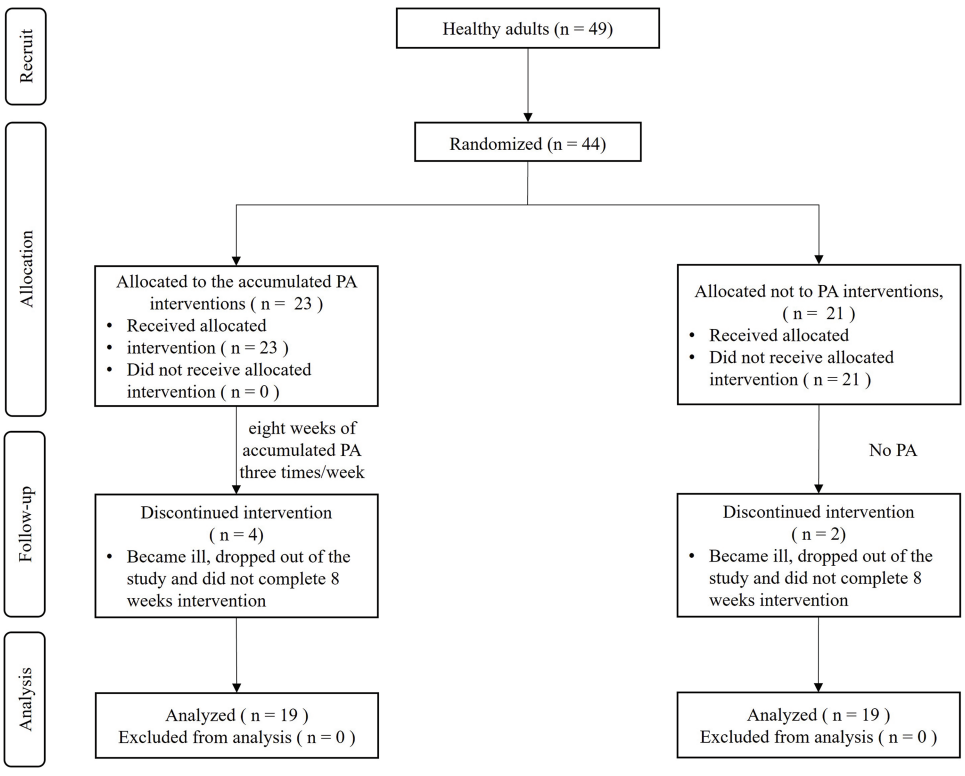

FIGURE 1. Research procedure.

TABLE 1

Demographic characteristics at pre-test

Characteristics	Accumulated group	Control group	*p*
	N = 23	*N* = 21	
Categorical variables, N (%)			
Gender			0.98
Female	11 (47.8%)	10 (47.6%)	
Education			0.09
High school diplomat	20 (87.0%)	21 (100%)	
College diplomat	3 (13.0%)		
Physical activity			0.48
None	4 (17.4%)	1 (4.8%)	
1 or 2 times a week	6 (26.1%)	8 (38.1%)	
3 or 4 times a week	7 (30.4%)	8 (38.1%)	
5 or 7 times a week	6 (26.1%)	4 (19.0%)	
Experience in using PA app			0.76
Yes	12 (52.2%)	10 (43.5%)	
No	11 (47.8%)	11 (52.4%)	
Continuos variables, *M*(*SD*)			
Age	23.17 (0.65)	22.19 (2.50)	0.08
BMI	22.20 (2.89)	23.56 (3.89)	0.19
Internet self-efficacy	4.00 (1.04)	3.74 (0.96)	0.38

Procedure

Survey data were collected at weeks zero and eight. Following the recruitment of participants, the initial survey commenced at week zero. Before the initial survey, the study commenced with an introduction, obtained participants' consent, and administered questionnaires through Google Forms. The participants accessed and completed surveys, including the Physical Activity Readiness Questionnaire (PAR-Q) [28], by following an online URL link. Subsequently, the participants were categorized into the accumulated group, which performed the assigned activities at various intervals throughout the day and week, whereas the control group did not engage in any particular PA. The intervention lasted for eight weeks based on the previous meta-analysis that demonstrated significant changes in mental health outcomes [29]. Identical surveys were conducted at week eight. All the surveys were conducted with complete anonymity. To verify that the questionnaires at weeks zero and eight were answered by the same person, unique IDs were provided to the participants for identification purposes.

The researchers conducted weekly participant management surveillance, confirming that the prescribed PA was completed through contact with the participants. When engaging in PA through the app, participants' activity duration, types, and intensity were recorded. The researchers obtained weekly confirmation photographs via messengers from the participants in the group, which detailed the PA frequency and duration for each week. The researchers documented weekly confirmations on a Google Sheet following the photo verification. This study was approved by the Hankuk University of Foreign Studies Institutional Review Board (IRB under reference HIRB-202404-HR-011). All participants signed the informed consent in this study. Potential participants were explicitly informed about the study goals and procedures, and only those who provided written informed consent were included.

Accumulated short bouts of PA intervention

This study utilized a tailored healthcare application that offers Artificial Intelligence (AI)-driven wellness services in PA domains. The application offers a "Training" service aimed at enhancing physical fitness through aerobic exercises and motion-sensing PA workouts. The app contains the 114 types of motion-sensing PA workout programs, including 32 stretching PA, 44 aerobic PA, 20 upper body resistance training, and 18 lower body resistance training. Based on these programs, the app suggests appropriate activities based on a simple survey, allowing users to directly configure their preferred PA type, intensity, and duration. Fitness logs enable users to track their prescribed PA levels and assess their overall physical condition. By leveraging motion-sensing technology, the application guarantees that users engage in PA with an accurate posture, enabling them to receive precise coaching as if they had a one-on-one personal trainer at home.

This study employed participant control using different PA strategies to verify the impact of accumulated short bouts of PA. Throughout the duration of the study, the accumulated group was mandated to divide their daily PA routine into two sessions, ensuring that each session took at least 10 min. They also performed PA three times a week. Thus, the accumulated group engaged in two 10-min sessions per day for three days per week. Additionally, participants in this group were given the freedom to select their preferred workout plan, with a specific emphasis on resistance training sessions.

Instruments

This study employed The Korean version of the Patient Health Questionnaire-9 (PHQ-9) to assess depression. This is a widely used self-report questionnaire designed to assess the severity of depressive symptoms among individuals. Developed by Spitzer et al. [30], it is based on the nine criteria for major depressive disorders in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV). Participants assessed the occurrence of symptoms during the last two weeks using a rating scale ranging from 0 to 3. The total score served as a measure of the intensity of depressive symptoms. The Cronbach's alpha coefficient of our study sample was 0.86, whereas that of the validation study was 0.81 [31]. Perceived stress was assessed using the Perceived Stress Scale (PSS) a widely used self-report instrument developed by Cohen et al. [32]. This questionnaire quantifies the extent to which individuals subjectively perceive their lives as stressful over the course of a month. The measure has 10 items wherein respondents assess the frequency of their stress-related feelings and thoughts using a Likert scale. Higher scores were correlated

with greater levels of perceived stress. In this study, our sample's Cronbach's alpha coefficient was 0.81, which matched the validation study's 0.80 [33]. Finally, we used the short versions of the Negative Affectivity Scale of Positive Affectivity and Negative Affectivity Scale (PANAS) [34] to assess the negative affectivity of student-athletes. The 5-point scale spanned from 1 (very slightly or not at all) to 5 (very strongly or extremely). The participants evaluated the degree to which they encountered each emotion within a designated period. The PANAS is widely used in psychology and psychiatric research to measure affective states. The internal consistency of the scale in this study was 0.75, which was similar to Kyral et al.'s [35] study of 0.77. Collectively, higher scores on the PHQ-9, PSS, and the Negative Affectivity Scale indicate greater levels of each symptom.

Data analysis

Initially, frequency and descriptive analyses were employed to compute the frequencies and percentages of categorical variables, as well as the means and standard deviations (*SD*) of continuous variables. Subsequently, a series of thorough analyses were conducted to analyze the discrepancies in the pre- and post-test across different groups. First, the methodology employed an independent sample *t*-test to examine the differences in the proposed variables between the two groups at pre- and post-test. Second, paired-sample *t*-tests were conducted within each group to independently compare the measurements obtained at the beginning and after the evaluation. Subsequently, a 2 (group) × 2 (time) repeated measures analysis of variance (RMANOVA) was performed, where pre- and post-test data were considered as dependent factors, and the group was treated as the independent variable.

Results

Results from the pre-test and post-test comparisons between the two group

The result from the pre-test in the accumulated (n = 23) and control groups (n = 21) are shown in Table 2. The results showed that the accumulation group had higher levels of depression (M = 5.56, SD = 4.42), anxiety (M = 0.55, SD = 0.54), perceived stress (M = 2.54, SD = 0.56), and negative affectivity (M = 1.71, SD = 0.54) than the control group (depression: M = 4.28, SD = 2.70; anxiety: M = 0.26, SD = 0.37; perceived stress: M = 2.34, SD = 0.52; and negative affectivity: M = 1.40, SD = 0.37). There were no statistically significant differences in any variables between the accumulated and control groups at the start of the trial.

Table 3 presents a concise overview of the comparisons between the two groups after the intervention. The control group exhibited significantly higher mean scores for depression (M = 4.57, SD = 3.54), anxiety (M = 0.36, SD = 0.37), perceived stress (M = 2.32, SD = 0.47), and negative affectivity (M = 1.52, SD = 0.57) than the accumulated control group (depression: M = 2.63, SD = 2.38; anxiety: M = 0.28, SD = 0.28; perceived stress: M = 2.21, SD = 0.46; and negative affectivity: M = 1.44, SD = 0.37). Again, no statistically significant differences were observed between groups for any variable. We used the paired-sample *t*-tests to assess whether there were significant differences in the levels of depression, anxiety, perceived stress, and negative affectivity based on the use of a mobile-based accumulated PA program (Tables 4 and 5).

The results for depression showed a decrease in the mean score from 5.56 ± 4.42 to 2.63 ± 2.38 for the accumulated group, and this difference was statistically significant (t_{40} = 2.59, p = 0.013). Relating perceived stress, the accumulated group also showed a significant decrease from 2.54 ± 0.56 to 2.21 ± 0.46 (t_{40} = 2.06, p = 0.046). Nevertheless, no statistically significant differences were observed between the pre- and post-test results for negative affectivity (t_{40} = 1.84, p = 0.073). In the control group, there was no statistically

TABLE 2

Mean differences between accumulated group and control group at pre-test

	Accumulated group, *M*(*SD*)	Control group, *M*(*SD*)	*t*	*p*-value	Cohen's *D*
Depression	5.56 (4.42)	4.28 (2.70)	1.14	0.26	0.34
Perceived stress	2.54 (0.56)	2.34 (0.52)	1.22	0.23	0.52
Negative affectivity	1.71 (0.54)	1.41 (0.37)	2.15	0.04	0.28

TABLE 3

Mean differences between accumulated group and control group at post-test

	Accumulated group, *M*(*SD*)	Control group, *M*(*SD*)	*t*	*p*-value	Cohen's *D*
Depression	2.63 (2.38)	4.57 (3.54)	−2.00	0.052	0.26
Perceived stress	2.21 (0.46)	2.32 (0.47)	−0.76	0.45	0.13
Negative affectivity	1.44 (0.37)	1.52 (0.57)	−0.53	0.60	0.36

TABLE 4

Mean differences between pre- and post-test for accumulated group

	Pre-test, *M*(*SD*)	Post-test, *M*(*SD*)	*t*	*p*-value	Cohen's *D*
Depression	5.56 (4.42)	2.63 (2.38)	2.59	0.013*	0.84
Perceived stress	2.54 (0.56)	2.21 (0.46)	2.06	0.046*	0.56
Negative affectivity	1.71 (0.54)	1.44 (0.37)	1.84	0.073	0.50

Note: *p < 0.05, **p < 0.01.

TABLE 5

Mean differences between pre- and post-test for control group

	Pre-test, M(*SD*)	Post-test, M(*SD*)	*t*	*p*-value	Cohen's *D*
Depression	4.28 (2.70)	4.57 (3.54)	−0.29	0.77	0.15
Perceived stress	2.34 (0.52)	2.32 (0.47)	0.12	0.90	0.11
Negative affectivity	1.40 (0.37)	1.52 (0.57)	−0.76	0.45	0.21

significant difference in the pre- and post-test results for any of the variables in the control group. Statistical analysis showed that the t-values and corresponding *p*-values were not significant (t_{40} = −0.29, p = 0.077 for depression; t_{40} = 0.12, p = 0.090 for perceived stress; and t_{40} = −0.76, p = 0.44 for negative affectivity).

Effectiveness of mobile-based accumulated PA program on the outcomes

As can be seen in Table 6 and Fig. 2, in the 2 (group) × 2 (time) RMANOVA, significant positive main effects of time were observed for depression score ($F_{1,\ 36}$ = 4.77, p = 0.036, η_p^2 = 0.12). However, no significant main effects of time were found for perceived stress ($F_{1,\ 36}$ = 3.34, p = 0.07, η_p^2 = 0.09) and negative affectivity ($F_{1,\ 36}$ = 1.40, p = 0.24, η_p^2 = 0.04). Furthermore, significant positive interaction effects between time and group were observed for depression ($F_{1,\ 36}$ = 6.59, p = 0.015, η_p^2 = 0.16). Nevertheless, no significant interaction impact was between group and time for perceived stress ($F_{1,\ 36}$ = 1.83, p = 0.18, η_p^2 = 0.05); negative affectivity ($F_{1,\ 36}$ = 3.63, p = 0.065, η_p^2 = 0.09).

Discussion

The primary objective of this study was to investigate the effects of accumulated short bouts of PA using mobile devices on mental health outcomes, specifically targeting depression, perceived stress, and negative affectivity among South Korean college students. This study included 44 healthy college students (23 in the accumulated group and 21 in the control group). The accumulated group showed significant decreases in depression and perceived stress, as demonstrated by paired-sample *t*-tests. The subsequent 2 × 2 RMANOVA confirmed these findings by showing a significant impact of time and interaction on depression. The following discussion synthesizes these findings to derive significant insights into the consequences of mental health interventions and effectiveness of mobile-based PA initiatives.

TABLE 6

Results from 2 × 2 RMANOVA

Variables	*df*	Time			Time * group		
		F	*p*-value	η_p^2	*F*	*p*-value	η_p^2
Depression	36	4.77	0.036*	0.12	6.9	0.015*	0.16
PS	36	3.34	0.076	0.09	1.83	0.181	0.05
NA	36	1.40	0.24	0.04	3.63	0.065	0.09

Note: *p < 0.05, **p < 0.01; PS = Perceived stress; NA = Negative affectivity.

One of the main findings of this study was that there were statistically significant reductions in both depression and perceived stress in the accumulated group. This finding indicates that even short and frequent engagement in PA facilitated by mobile devices can offer tangible mental health benefits in terms of mitigating the symptoms of depression and perceived stress. Previous studies have reported that even brief periods of PA (10-min) have the potential to induce the secretion of endorphins and neurotransmitters that are positively correlated with the emotions of joy [36,37]. This neurochemical reaction has the potential to enhance mood and function as an inherent safeguard against symptoms associated with depression and stress [38,39]. This finding contributes to the existing body of knowledge supporting the effectiveness of mobile-based PA in promoting mental health. More importantly, this is the first study to identify the significant impact of accumulated PA interventions on depression and perceived stress within a mobile context. Previous studies have often focused on continuous PA interventions in the mobile context [15–18] or accumulated PA interventions in traditional in-person settings [20–23]. By integrating the two unique contexts of accumulated and mobile settings, the current study demonstrates the importance of short and frequent interventions, establishing mobile-based accumulated PA as a feasible approach to improve mental health.

Additionally, the findings from the 2 × 2 RMANOVA provided additional support for the significant efficacy of the accumulated PA program, revealing a significant interaction effect of group and time on depressive symptoms. The unique impact of the accumulated PA program on depression highlights its significant contribution to the improvement of mental health, thus adding to our understanding of the effects of diverse PA programs. This resonates with previous literature advocating diverse approaches to PA interventions for mental health, acknowledging the potential effectiveness of novel formats such as accumulated bouts within mobile settings. The theoretical implications of these findings extend to a broader framework of mental health intervention strategies. The distinctive impact of the accumulated PA program on depression, as evidenced by the interaction effects, challenges the traditional views of uniform mental health interventions. It suggests that tailoring interventions to include accumulated short bouts of physical activity can yield specific and favorable mental health outcomes. Integrating these findings into theoretical models of mental health interventions broadens our perspectives and encourages more context-specific approaches.

Finally, this study found that neither type of PA significantly reduces negative affectivity. This result is consistent with previous literature that has also found insignificant relationships between PA and negative affectivity [40,41]. The lack of impact may be attributed to the intensity and duration of the PA sessions. Research indicates that longer duration PA sessions, particularly those

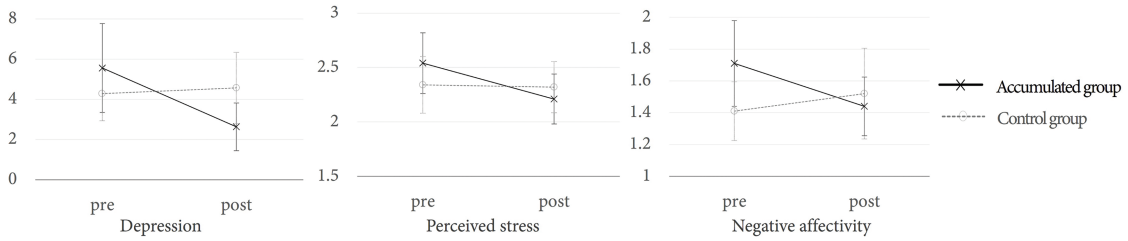

FIGURE 2. Results from the interaction analysis.

lasting 30-min or more, are often associated with greater improvements in mood. In this study, the participants engaged in PA for approximately 20-min, which may have been relatively short in duration, thereby potentially limiting its effectiveness in eliciting significant changes in negative affectivity.

Practical implications

The findings of this study offer significant practical implications for the design and implementation of PA programs, particularly those that leverage mobile technologies. These implications address real-world problems and benefit-specific groups and provide guidelines for their implementation.

The physical and mental benefits of physical activity have been widely acknowledged by many people. The complexities of everyday schedules and preparatory procedures impede access to physical activities. This study demonstrates how participating in short bursts of physical activity can overcome obstacles and provide a way to obtain the physical and emotional benefits of physical activity despite a hectic schedule. This method of collecting brief exercise periods has important implications for creating practical mobile-based physical activity regimens. Our findings offer a temporal framework to assist in developing PA program apps and home training programs. They provide evidence-based recommendations on the frequency and duration of activities required to attain health benefits.

Our study focused on the benefits of an eight-week physical activity program for a specific group of healthy people in their twenties. Depression, stress, negative affectivity, and well-being were assessed. The results confirmed that repeated episodes of physical activity could effectively decrease depression and stress in this specific group. These findings indicate that smartphone fitness apps can provide programs that promote both physical and mental well-being. Identifying the most effective frequencies and shortest exercise durations can improve the effectiveness of these physical activity programs and increase their benefits for participants.

These insights highlight the potential utility of physical activity programs designed to include accumulated short bouts of physical activity for groups constrained by the lack of prolonged periods available for exercise. In South Korea, the prevalence of demanding work schedules makes it challenging for many office workers to dedicate time to exercise post-work. By integrating the concept of accumulated short bouts of physical activity using mobile devices, these individuals could leverage brief periods of exercise facilitated by mobile phones to achieve positive psychological effects. Furthermore, individuals living in rural areas, who might face difficulties in accessing gym facilities or personal training programs, could benefit from engaging in these activities at home, without the need for specialized spaces. For older adults, particularly those who are physically frail, engaging in high-intensity exercise may not be feasible. Offering accumulated bouts of exercise programs through mobile devices that allow for not only positive physiological effects [22] but also psychological outcomes.

The experimental group in our study participated in a physical activity regimen that included two 15-min sessions, three days per week. The eight-week program, consisting of multiple sessions of physical activity, was highly successful in decreasing the symptoms of depression and stress. These findings suggest that PA programs designed for mental health benefits can be effective when delivered in shorter, segmented sessions rather than in longer, continuous sessions. This indicates that providers of app-based physical activity programs may obtain better results by providing programs of shorter durations. Our research recommends setting criteria for the frequency and duration of physical activity programs provided through smartphone health management apps because long-duration physical activity can be difficult to incorporate into busy schedules. Moreover, this method is suitable for those looking to work out at home as it promotes the idea of participating in several sessions instead of trying to make time for longer exercise routines.

The implications of this research extend beyond academic interests and offer practical evidence-based guidance for the development of PA interventions. These interventions, particularly when delivered through mobile platforms, have the potential to contribute significantly to public health by enhancing accessibility and compliance with PA recommendations, ultimately improving mental health outcomes in the general population.

Limitations and Future Research Directions

This study has some limitations, and recommendations for future research are proposed. First, we encountered difficulties in randomizing the enrolled participants into intervention and control groups. Participants who demonstrated willingness to participate in PA and received approval from the researchers were enrolled in the treatment group. This self-selection process may have introduced bias, as individuals with specific characteristics or motivations may have been more inclined to participate in the study, potentially influencing the outcomes. Thus,

caution should be exercised when interpreting the outcomes of the accumulated PA program in this study. Future studies should reassess the findings of this investigation using a randomized allocation study.

Moreover, the generalizability of this study is limited by its exclusive focus on healthy college students. Hence, these findings may not be broadly applicable to heterogeneous populations or varied mental healthcare environments. Future studies should explore a broader range of individuals to improve the generalizability of the results. For example, a follow-up study could include individuals diagnosed with depression to examine the impact of accumulated PA on depressive symptoms in the clinical environment. Further investigation should focus on the older adult population. In the similar vein, the relatively small sample size may restrict the generalizability of findings. As such, caution should be emphasized when applying the results to larger and more diverse populations. Future research efforts should aim to address this limitation by recruiting a larger and more heterogeneous sample to improve the external validity of the study findings. Additionally, expanding the sample size would enable researchers to explore potential subgroup differences and better understand the nuanced effects of the intervention across different demographic groups.

Furthermore, the study evaluated the participants' results at two specific moments: the first assessment and the post-test. Nevertheless, a more extended period of observation would be beneficial in order to assess the long-term durability of the impacts of PA programs. Hence, it is recommended that future studies prolong the duration of follow-up in order to evaluate the enduring impact of PA interventions. This will allow for a better understanding of the sustainability of the reported results and the possibility of intervention benefits diminishing with time.

Finally, the nonsignificant results for negative affectivity should prompt a closer examination of the intervention components. Assessing whether the intervention addresses specific facets of negative affectivity could offer insights into potential areas for improvement or optimization. This in-depth examination sought to uncover the reasons for the lack of significant results in these areas. This provides an opportunity to pinpoint particular aspects of the intervention that may require refinement or optimization to enhance its efficacy in addressing negative affectivity. Essentially, it advocates a more nuanced evaluation of the intervention's impact on specific outcomes, facilitating an informed and targeted approach to future interventions or adjustments to the existing program.

Conclusion

This study aimed to investigate the impact of mobile-based PA programs, conducted in short intervals, on mental health indicators with a specific focus on depression, perceived stress, and negative affectivity among college students in South Korea. The results indicated a significant decrease in depression and perceived stress in the experimental group, whereas the control group did not show any meaningful differences. The results of the 2 × 2 RMANOVA demonstrated a clear and significant relationship between time and depression scores. This finding highlights the potential influence of physical activity accumulated through mobile devices on mental health outcomes. These findings add to the increasing amount of research highlighting the positive effects of flexible and easily accessible PA programs on mental health. Furthermore, this provides a practical alternative for people with busy schedules who find it difficult to participate in longer, continuous physical activity sessions. These findings underscore the importance of integrating such interventions into public health policies aimed at promoting mental well-being among young adults. Furthermore, in the realm of mobile health application development, our study highlights the significance of incorporating features that support and encourage participation in mobile-based PA interventions tailored to the unique needs and preferences of college students.

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Availability of Data and Materials: The data that support the findings of this study are available upon reasonable request.

Ethics Approval: This study was approved by the Hankuk University of Foreign Studies Institutional Review Board (IRB under reference HIRB-202404-HR-011). All participants signed the informed consent in this study.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

References

1. OECD (Organization for Economic Cooperation and Development). Suicide rate estimates, crude estimates by country. 2023. Available from: http://apps.who.int/gho/data/view.main.MHSUICIDEv?lang=en. [Accessed 2023].
2. Lee E, Kim W. A study on the effect of the infectious disease disaster on the mental health due to COVID-19. Gyeonggi-do, Korea: Gyeonggi Research Institute; 2021.
3. Jeon K, Song Y, Chae C. The survey on the human rights situation of impoverished youth. Seoul, Korea: National Human Rights Commission of Korea; 2019.

4. Centers for Disease Control and Prevention. Benefits of physical activity. 2023. Available from: https://www.cdc.gov/physicalactivity/basics/pa-health/index.htm. [Accessed 2023].
5. Mayo Clinic. Physical activity: 7 benefits of regular physical activity. 2023. Available from: https://www.mayoclinic.org/healthy-lifestyle/fitness/in-depth/exercise/art-20048389. [Accessed 2023].
6. Recchia F, Bernal JDK, Fong DY, Wong SHS, Chung PK, Chan DKC, et al. Physical activity interventions to alleviate depressive symptoms in children and adolescents: a systematic review and meta-analysis. JAMA Pediatr. 2023;177(2):132–40. doi:10.1001/jamapediatrics.2022.5090.
7. Singh B, Olds T, Curtis R, Dumuid D, Virgara R, Watson A, et al. Effectiveness of physical activity interventions for improving depression, anxiety and distress: an overview of systematic reviews. Br J Sports Med. 2023;57(18):1203–9. doi:10.1136/bjsports-2022-106195.
8. Stanton R, Happell B, Reaburn P. The mental health benefits of regular physical activity, and its role in preventing future depressive illness. Nurs Res Rev. 2014;4:45–53.
9. Li WJ, Gao YC, Liu GQ, Hao RK, Zhang MJ, Li XT. Shifting the paradigm: a fresh look at physical activity frequency and its impact on mental health, life satisfaction, and self-rated health in adolescents. Int J Ment Health Promot. 2024;26(2):83–92. doi:10.32604/ijmhp.2023.042014.
10. Su J, Wei E, Clark C, Liang K, Sun X. Physical exercise, sedentary behaviour, sleep and depression symptoms in chinese young adults during the COVID-19 pandemic: a compositional isotemporal analysis. Int J Ment Health Promot. 2022;24(5):759–69. doi:10.32604/ijmhp.2022.020152.
11. World Health Organization. Global recommendations on physical activity for health. Geneva: World Health Organization; 2010.
12. Gettman LR, Pollock ML, Ward A. Adherence to unsupervised exercise. Phys Sportsmed. 1983;11(10):56–66. doi:10.1080/00913847.1983.11708657.
13. Ziebland S, Thorogood M, Yudkin P, Jones L, Coulter A. Lack of willpower or lack of wherewithal? "Internal" and "external" barriers to changing diet and exercise in a three year follow-up of participants in a health check. Soc Sci Med. 1998;46(4):461–5.
14. Kim H, Lee K, Lee YH, Park Y, Park Y, Yu Y, et al. The effectiveness of a mobile phone-based physical activity program for treating depression, stress, psychological well-being, and quality of life among adults: quantitative study. JMIR Mhealth Uhealth. 2023;11:e46286. doi:10.2196/46286.
15. Chung J, Kim K, Hong J, Kong HJ. Effects of prolonged exercise versus multiple short exercise sessions on risk for metabolic syndrome and the atherogenic index in middle-aged obese women: a randomised controlled trial. BMC Womens Health. 2017;17(1):65. doi:10.1186/s12905-017-0421-z.
16. Panter JR, Jones AP. Associations between physical activity, perceptions of the neighbourhood environment and access to facilities in an English city. Soc Sci Med. 2008;67(11):1917–23. doi:10.1016/j.socscimed.2008.09.001.
17. Firth J, Torous J, Nicholas J, Carney R, Pratap A, Rosenbaum S, et al. The efficacy of smartphone-based mental health interventions for depressive symptoms: a meta-analysis of randomized controlled trials. World Psychiatry. 2017;16(3):287–98. doi:10.1002/wps.v16.3.
18. Vandelanotte C, Duncan MJ, Plotnikoff RC, Rebar A, Alley S, Schoeppe S, et al. Impact of a web-based personally tailored physical activity intervention on depression, anxiety, stress and quality of life: secondary outcomes from a randomized controlled trial. Ment Health Phys Act. 2022;23:100477. doi:10.1016/j.mhpa.2022.100477.
19. Pate RR, Pratt M, Blair SN, Haskell WL, Macera CA, Bouchard C, et al. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. JAMA. 1995;273(5):402–7. doi:10.1001/jama.1995.03520290054029.
20. Eguchi M, Ohta M, Yamato H. The effects of single long and accumulated short bouts of exercise on cardiovascular risks in male Japanese workers: a randomized controlled study. Ind Health. 2013;51(6):563–71. doi:10.2486/indhealth.2013-0023.
21. Zhang X, Zheng C, Ho RST, Miyashita M, Wong SHS. The effects of accumulated versus continuous exercise on postprandial glycemia, insulin, and triglycerides in adults with or without diabetes: a systematic review and meta-analysis. Sports Med Open. 2022;8(1):14. doi:10.1186/s40798-021-00401-y.
22. Murphy MH, Lahart I, Carlin A, Murtagh E. The effects of continuous compared to accumulated exercise on health: a meta-analytic review. Sports Med. 2019;49(10):1585–607. doi:10.1007/s40279-019-01145-2.
23. Quinn TJ, Klooster JR, Kenefick RW. Two short, daily activity bouts vs. one long bout: are health and fitness improvements similar over twelve and twenty-four weeks? J Strength Cond Res. 2006;20(1):130–5.
24. Osei-Tutu K, Campagna P. The effects of short- vs. long-bout exercise on mood, VO_2max, and percent body fat. Prev Med. 2005;40:92–8. doi:10.1016/j.ypmed.2004.05.005.
25. Murphy M, Nevill A, Neville C, Biddle S, Hardman A. Accumulating brisk walking for fitness, cardiovascular risk, and psychological health. Med Sci Sports Exer. 2003;34(9):1468–74.
26. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods. 2007;39(2):175–91. doi:10.3758/BF03193146.
27. Richards D, Richardson T. Computer-based psychological treatments for depression: a systematic review and meta-analysis. Clin Psychol Rev. 2012;32(4):329–42. doi:10.1016/j.cpr.2012.02.004.
28. Thomas S, Reading J, Shephard RJ. Revision of the physical activity readiness questionnaire (PAR-Q). Can J Sport Sci. 1992;17(4):338–45.
29. Mammen G, Faulkner G. Physical activity and the prevention of depression: a systematic review of prospective studies. Am J Prev Med. 2013;45(5):649–57. doi:10.1016/j.amepre.2013.08.001.
30. Spitzer RL, Kroenke K, Williams JBW, Patient Health Questionnaire Primary Care Study Group. Validation and utility of a self-report version of PRIME-MD the PHQ primary care study. JAMA. 1999;282(18):1737–44. doi:10.1001/jama.282.18.1737.
31. Park SJ, Choi HR, Choi JH, Kim KW, Hong JP. Reliability and validity of the Korean version of the patient health questionnaire-9 (PHQ-9). Anxiety Mood. 2010;6(2):119–24.
32. Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. J Health Soc Behav. 1995;24(4):385–96. doi:10.2307/2136404.
33. Frank SH, Zyzanski SJ. Stress in the clinical setting: the brief encounter psychosocial instrument. J Fam Pract. 1988;26(5):533–9.

34. Watson D, Clark LA, Tellegen A. Development and validation of brief measures of positive and negative affect: the PANAS scales. J Pers Soc Psychol. 1988;54(6):1063. doi:10.1037/0022-3514.54.6.1063.
35. Kyral A, Shipherd A, Hearon C. The effect of moderate intensity aerobic exercise on affect and exercise intention in active and inactive college students. Int J Exer Sci. 2019;12:1070–9.
36. Schwarz L, Kindermann W. Changes in β-Endorphin levels in response to aerobic and anaerobic exercise. Sports Med. 1992;13(1):25–36. doi:10.2165/00007256-199213010-00003.
37. Sharifi M, Hamedinia MR, Hosseini-Kakhak SA. The effect of an exhaustive aerobic, anaerobic and resistance exercise on serotonin, beta-endorphin and BDNF in students. Phys Educ Students. 2018;22(5):272–7. doi:10.15561/20755279.2018.0507.
38. Hegadoren KM, O'Donnell T, Lanius R, Coupland NJ, Lacaze-Masmonteil N. The role of β-endorphin in the pathophysiology of major depression. Neuropeptides. 2009;43(5):341–53. doi:10.1016/j.npep.2009.06.004.
39. Alizadeh Pahlavani H. Possible role of exercise therapy on depression: effector neurotransmitters as key players. Behav Brain Res. 2024;459:114791. doi:10.1016/j.bbr.2023.114791.
40. Kanning M, Ebner-Priemer U, Schlicht W. Using activity triggered e-diaries to reveal the associations between physical activity and affective states in older adult's daily living. Int J Behav Nutr Physi Act. 2015;12:111. doi:10.1186/s12966-015-0272-7.
41. Lia Y, Chou C, Huh J, Leventhal A, Dunton G. Examining acute bi-directional relationships between affect, physical feeling states, and physical activity in free-living situations using electronic ecological momentary assessment. J Behav Med. 2017;40(3):445–57. doi:10.1007/s10865-016-9808-9.