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A longitudinal study on the bidirectional relationship between adolescents' physical activity and life satisfaction

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The *purpose of this study was to investigate the longitudinal relationship between physical activity and life satisfaction in adolescents. We used Autoregressive Cross-lagged Model (ACLM) to investigate the longitudinal relationship and utilized four years of data (N = 1,897) from the Korean Children and Youth Panel Survey, which was conducted by the National Youth Policy Institute. Results showed that physical activity and life satisfaction were found to be s over time. In addition, we found that physical activity at a previous time point had a significant and consistent impact on life satisfaction at subsequent time points. Conversely, life satisfaction at a previous time point was found to have a consistent effect on physical activity at the subsequent time point. This study demonstrates that physical activity and life satisfaction mutually influence and impact each other, indicating that they have a reciprocal relationship. In conclusion, it is noteworthy that life satisfaction has a strong influence in predicting physical activity, and that it needs to be considered as a priority and acts as a motivational factor for specific* behaviors.

KEY WORDS: Adolescent, Physical activity, life satisfaction, Autoregressive cross-lagged model

Introduction

Traditionally, the majority of psychologists have primarily focused on the negative aspects of human nature, such as depression, stress, and anxiety, with the aim of overcoming them; this emphasis on the negative aspects has resulted in an imbalance within psychological research, as it heavily invests in study-

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ing the negative aspects of human psychology (Seligman, 2019). Consequently, since the 1990s, there was a shift in researchers' interest towards positive psychology to address this imbalance (Csikszentmihalyi & Seligman, 2000; Lee & Cho, 2023). Positive psychology explores happiness, quality of life, and the conditions and processes of life satisfaction by exerting positive potential (e.g., Cho, 2021; Lee et al., 2023; Roslan & Cho, 2024). Positive psychology aims to explore happiness, quality of life, and the conditions and processes that lead to life satisfaction by harnessing positive potential (Seligman et al., 2005).

The rise of positive psychology highlighted that a mentally healthy state for individuals does not imply a complete absence of problems but rather the pursuit of a better quality of life (Arthaud-Day et al., 2005). As a result, researchers have directed their efforts toward investigating factors that can explain quality of life and life satisfaction across various fields of study, including sport psychology, leisure, and education (Cho, 2020; Cho & Lee, 2022; Lewis et al., 2011; Shander &Petrie, 2021; Zayed et al., 2018). Collectively, recent research suggests that various factors, such as positive emotions, nostalgia, gratitude, social support, personal values, and other determinants, can enhance life satisfaction and promote overall well-being (Blau et al., 2019; Cho et al., 2020, 2021, 2023; Cho & Kang, 2023; Kong et al., 2019; Xiang & Yuan, 2021; Lamela & Figueiredo, 2023). In other words, positive psychology has the potential to assist individuals in leading more fulfilling and meaningful lives by focusing on the positive aspects of human experience.

Among various factors related to positive psychology, this study specifically focuses on life satisfaction, which refers to the cognitive evaluation of one's fulfillment in various aspects of their current life status, without desiring significant changes (Diener & Seligman, 2002). Within the literature, researchers have shown significant interest in examining the life satisfaction of adolescents (Marcionetti & Rossier, 2016; Moksnes & Espnes, 2013). Adolescents can be defined as individuals who have gained self-identifying abilities through cognitive development and have achieved a level of independence from their parents (World Health Organization, n.d.). Researchers have found that adolescents, being in the developmental stage between childhood and adulthood, often experience a relatively unstable state of quality of life and life satisfaction. For instance, Park and Huebner (2005) revealed that South Korean adolescents reported lower levels of life satisfaction compared to their counterparts in the United States. South Korea's robust focus on education, coupled with rapid economic development, has engendered several societal challenges (Jung, 2020). These include the financial strain associated with private education costs, heightened competition in entrance examinations, and escalating socio-economic disparities between affluent and disad-

vantaged segments of the population. This disparity may be attributed to the excessive mental stress stemming from a highly competitive school environment and the emphasis on college-focused education in South Korea.

Life satisfaction of adolescents is highly affected by various external factors. One such factor is physical activity, which has been shown to improve adolescents' life satisfaction through multiple mechanisms, including the release of endorphins (Pangkahila et al., 2016), reduced stress (Vogel et al., 2022), improved self-esteem (Liu et al., 2015), increased social connectedness (Franke et al., 2021), and enhanced cognitive function (Ploughman, 2008). This highlights the necessity of research aimed at enhancing adolescents' life satisfaction. Furthermore, the World Health Organization (2010) and the Department of Health and Human Services (2018) suggest that adolescents are required to engage in moderate-to-vigorous intensity physical activity for more than 60 minutes daily. However, a survey conducted by the WHO revealed that 77.6% of male students and 84.7% female students around the globe lacked involvement for physical activity (Guthold et al., 2020). This indicates that the majority of students were not sufficiently involved in physical activity. Notably, the issue is particularly pronounced in South Korea, where 91.4% of male students and 97.2% of female students were found to lack physical activity according to a 2016 survey, highlighting a serious concern. In addition, the level of physical activity of adolescents was ranked 37th out of 57 countries and was rated at D- (Aubert et al., 2022).

Previous research has revealed positive correlations between life satisfaction and various factors, such as the quality of social relationships, active engagement in school life, positive self-concept, and health behavior (Chui & Wong, 2016; Lee et al., 2023; Lewis et al., 2011; Proctor et al., 2009; Raboteg-Saric & Sakic, 2014; Zullig et al., 2005). Of particular interest is the correlation between physical activity and life satisfaction, which has been extensively discussed from two related perspectives. The first perspective questions whether participation in physical activity leads to higher life satisfaction, while the second perspective explores whether individuals with higher life satisfaction engage in higher levels of physical activity. Ongoing discussions on this topic have resulted in various opinions supporting the existence of reciprocal relationships between life satisfaction and physical activity (Steptoe, 2019).

Contrasting Perspectives On Physical Activity And Life Satisfaction

In line with research advocating physical activity as a contributing factor to life satisfaction, several perspectives have been proposed. You et al.

(2021) conducted a longitudinal study to examine the effect of physical activity on life satisfaction. Their findings revealed that physical activities have a positive impact on resolving issues such as depression, anxiety, and stress, while also reducing negative emotional expressions like aggression and destructive behavior. They emphasized that physical activity plays a significant role in improving life satisfaction within this problem-solving process. Furthermore, Pedišić et al. (2015) investigated the relationship between the intensity of different types of physical activity (work, transport, domestic, and leisure-time) and life satisfaction. Surprisingly, they found that only vigorous-intensity physical activity during leisure-time showed a weak but positive relationship with life satisfaction. This contradicted previous predictions that various forms of physical activity would contribute to life satisfaction. To explain this result, Pedišić et al. referred to the activity theory, which suggests that life satisfaction is influenced by the frequency of physical activity participation and the level of intimacy with the activity (Havighurst, 1963). In this context, intimacy refers to familiarity or the extent to which one is closely associated with a specific physical activity (Jamieson, 1998). Although previous research did not explicitly consider the level of intimacy related to physical activity, the overall findings showed that physical activity positively influences life satisfaction.

On the other hand, some previous studies suggest that higher life satisfaction and well-being are necessary conditions for promoting physical activity. For instance, Kim et al. (2017) conducted a longitudinal study using 11 years of data from U.K. adults to investigate the relationship between psychological well-being and physical activity. Kim et al. found that adults who had higher psychological well-being and were relatively physically active at the beginning of the study were less likely to become physically inactive over time. Conversely, adults who were relatively inactive at the beginning but had higher psychological well-being were more likely to become more physically active. In addition, in an eight-year longitudinal study, Azevedo Da Silva et al. (2012) reported that participants with anxiety or depression were highly unlikely to meet the appropriate level of physical activity. While lower levels of depression cannot be directly equated to higher life satisfaction, these findings demonstrate that a higher negative index among individuals hinders their participation in physical activity. Similarly, Kim et al. (2021) conducted a four-year longitudinal study and found that a high level of life satisfaction decreased mortality rates and lowered the incidence of chronic diseases, while increasing physical activity participation. In addition, a high level of life satisfaction leads to significant improvements in psychosocial indicators, reducing depression, negative emotions, and loneliness (Kim

et al., 2021). Kubzansky and Thurston (2007) also examined the influence of healthy psychological function on physical health and noted that emotional vitality was associated with a reduced risk of coronary heart disease. The basis of this mechanism is understood to arise from motivational factors influencing health-promoting behaviors. This can be seen as the fact that life satisfaction plays a positive role in psychological processes such as goal setting, self-regulation, and self-efficacy, which have an important influence on health behavior decisions (van Stralen et al., 2009). Taken together, these studies suggest that life satisfaction and a positive evaluation of one's life play significant roles in sustaining physical activity in the long term. In other words, individuals with higher levels of life satisfaction and psychological well-being are more likely to engage in regular physical activity, while those with lower well-being or mental health challenges may face barriers to physical activity participation.

Purpose of this study

Both of the aforementioned perspectives acknowledge the significance of physical activity and life satisfaction, yet the exact direction of the effect remains inconclusive. The relationship between life satisfaction and physical activity is presumed to be bidirectional; however, it remains ambiguous. Thus, it is imperative to enhance explanatory capacity by concurrently examining both variables (Grant et al., 2009). Furthermore, the need to evaluate this relationship is growing, given that numerous countries are now considering not only traditional economic metrics but also levels of well-being, such as life satisfaction, as guiding principles in policy formulation (Kim et al., 2021). It is important to note that physical activity and life satisfaction exhibit interconnected relationships rather than a clear-cut bidirectional causal relationship at the cross-sectional level (Kim et al., 2017; Pedišić et al., 2015; You et al., 2021). The limitation of cross-sectional studies lies in their inability to capture the dynamic nature of physical activity and life satisfaction, as both variables demonstrate repetitive patterns in an individual's life. To overcome this limitation, a longitudinal approach that considers both variables simultaneously is more appropriate for exploring their relationship (Martín-María et al., 2020; Yemiscigil & Vlaev, 2021). Therefore, we adopt a holistic approach to investigate the relationship between physical activity and life satisfaction.

This study aims to explore the bidirectional causal relationship between these variables in adolescents over a four-year time span. This attempt has the strength of overcoming the limitations of cross-sectional research and examin-

ing longitudinal relationships between the variables. Specifically, although the physical activity variable was initially considered independent, it can also be a dependent variable in the causal relationship. It indicates that both physical activity and life satisfaction can affect and depend on each other. Therefore, this study conducted a longitudinal causal relationship test to identify which variable better explains the specific causal relationship. The first objective of this study is to investigate whether there is any variation in physical activity or life satisfaction over time. This study hypothesized that participation in physical activity and the level of life satisfaction in the previous year would be positively associated with similar or increased participation in physical activity and life satisfaction in the following year. This approach allows us to identify the changes in physical activity participation and life satisfaction over time. Second, we examined the relationship between physical activity and life satisfaction over a specific time period. The significance of this analysis lies in its potential to provide more effective guidance for promoting physical activity and life satisfaction. By revealing the directional and/or longitudinal relationship between physical activity and life satisfaction, we aim to contribute valuable insights that can assist policymakers in developing more effective strategies to enhance both physical activity and life satisfaction. The hypotheses formulated to achieve the objectives of this study are as follows:

H1: Physical activity will be stable over time.
H2: Life satisfaction will be stable over time.
H3: Physical activity will affect life satisfaction over time.
H4: Life satisfaction will affect physical activity over time.

Methods

Participants

This study utilized data from the Korean Children and Youth Panel Survey, which was conducted by the National Youth Policy Institute over a seven-year period from 2010 to 2016. Due to the limitations imposed by the COVID-19 pandemic, we were unable to access more recent data. In other words, it was the most recent and available secondary data in Korea. Specifically, we focused on the 1st year of the middle school panel in the survey, and a multistage stratified cluster sampling method was employed. The data from a four-year period, spanning from 2012 to 2015 (referred to as t3 to t6), were selected for this study. These years were chosen because they were the only time points during which both physical activity and life satisfaction were measured. Out of the 2,351 students who attended their first year of middle school, we excluded 454 cases with missing values (i.e., In case of missing response more than once in longitudinal measurement over 4 years), resulting in a final sample size of 1,897 students (963 male students and 934 female students).

Measurements

This study measured the relationship between physical activity and life satisfaction. Table 1 presents the descriptive statistics. First, to determine physical activity participation, we utilized a single question from the Korean Children and Youth Panel Survey: "How many hours have you participated in physical activity last week?" The responses ranged from (1) not at all to (5) more than four hours. A higher response score indicates greater participation in physical activity. This questionnaire aligns with the physical activity participation variable used in the study by Lee and Lim (2019). However, since the physical activity variable consists of a single item, we were unable to calculate Cronbach's α. Next, to measure individuals' satisfaction with their lives, we selected three questions from the Korean Children and Youth Panel Survey: (1) I find my life to be pleasing, (2) I have almost no concerns with my life, and (3) I believe I am living a happy life. The response options ranged from (1) very much to (4) not at all. The Cronbach's α for the life satisfaction variables from 2012 to 2015 were .089, .802, .776, and .817, respectively. (Table I)

Data Analysis

In this study, frequency analysis, reliability analysis, and correlation analysis were performed on the panel data. To verify the longitudinal causal relationship between physical activity and life satisfaction in adolescents, Autoregressive Cross-lagged Model (ACLM) was applied to confirm the bidirectional relationship. In ACLM, the value of t at a specific time point is explained by the value t-1 at previous time point. Furthermore, by extending autoregressive model to multivariate model to estimate cross-lagged effect of physical activity in the previous year on life satisfaction in the following year. ACLM analysis requires three conditions that must be satisfied sequentially over time: metric invariance, path coefficient invariance, and error covariance invariance (Finkel, 1995). First, metric invariance tests whether the measured

Table I.
Descriptive Statistics

Variables	Obs.	Mean	SD	Min.	Max.
PA1	1897	2.980	1.344	1	5
PA2	1897	2.630	1.121	1	5
PA3	1897	2.510	1.147	1	5
PA4	1897	1.730	1.151	1	5
LS1	1897	2.845	.664	1	4
LS2	1897	2.826	.603	1	4
LS3	1897	2.798	.582	1	4
LS4	1897	2.878	.614	1	4

Note. PA1 = physical activity level in the first year; PA2 = physical activity level in the second year; PA3 = physical activity level in the third year; PA4 = physical activity level in the fourth year; LS1 = life satisfaction level in the first year; LS2 = life satisfaction level in the second year; LS3 = life satisfaction level in the third year; LS4 = life satisfaction level in the fourth year. $^{**}p < .01$, $^{***}p < .001$

concept is homogeneous by respondents over time. Second, path coefficient invariance tests the homogeneous regression coefficients for latent variables for the measured concept over time. Last, error covariance invariance checks whether there is a correlation between the measurement errors of physical activity and life satisfaction. By adding an equalization constraint to the covariance between the errors, it verifies if the correlation remains constant over time. These sequential conditions of metric invariance, path coefficient invariance, and error covariance invariance are essential in ACLM analysis to examine the bidirectional relationship between physical activity and life satisfaction in adolescents.

Results

Correlation And Descriptive Statistics

Table 2 presents the results of analyzing the correlation between physical activity and life satisfaction variables. The findings demonstrate a significant positive correlation between physical activity and life satisfaction each year. Additionally, when examining the average values of physical activity and life satisfaction over the four-year period, physical activity exhibited a relatively larger distribution ranging from 1.73 to 2.98. On the other hand, life satisfaction showed a relatively smaller distribution ranging from 2.798 to 2.878. (Table II)

Table II.
Correlation of Variables

Variable		1	2	3	4	5	6	7	8
1.	PA1	1							
2.	PA2	.297**	1						
3.	PA3	.296**	.375**	1					
4.	PA4	.205**	.303**	.313**	1				
5.	LS1	.098**	.130**	.106**	.133**	1			
6.	LS2	.080**	.126**	.128**	.109**	.467**	1		
7.	LS3	.107**	.138**	.154**	.135**	.434**	.534**	1	
8.	LS4	.096**	.114**	.112**	.138**	.342**	.476**	.533**	1

Note. PA1 = physical activity level in the first year; PA2 = physical activity level in the second year; PA3 = physical activity level in the third year; PA4 = physical activity level in the fourth year; LS1 = life satisfaction level in the first year; LS2 = life satisfaction level in the second year; LS3 = life satisfaction level in the third year; LS4 = life satisfaction level in the fourth year. **p < .01

ACLM of adolescent physical activity and life satisfaction

This study employed Autoregressive Cross-lagged Modeling (ACLM) to investigate the longitudinal causal relationship between physical activity and life satisfaction in adolescents. The analysis involved examining seven sequential models.

(1) Model 1: This basic model included no identification constraints except for the covariance between errors in the research model.
(2) Model 2: Identification restrictions were applied to the measurement variables of life satisfaction to assess the same understanding of life satisfaction over time. Since metric invariance could not be tested with a single question in physical activity, only life satisfaction was investigated in this model.
(3) Model 3: Path coefficient invariance was tested by applying identification constraints to confirm the same autoregressive coefficients for life satisfaction over time.
(4) Model 4: Path coefficient invariance was tested by using an equalization constraint to verify the same autoregression coefficient for physical activity over time.
(5) Model 5: Path coefficient invariance was tested through identity constraints to confirm the same coefficients for the effect of life satisfaction at time [t-1] on physical activity at time [t] over time.
(6) Model 6: Path coefficient invariance was tested by applying identification constraints to confirm the same coefficients for the effect of physical activity at time [t-1] on life satisfaction at time [t] over time.
(7) Model 7: Error covariance invariance was tested by applying an equalization constraint to the covariance between the errors in physical activity and life satisfaction over time.

To find the ideal model among the seven candidates, models 1 to 7 were sequentially compared and verified. The comparison between models used various statistical indices, including Root Mean Square Error of Approximation (RMSEA), Standardized Root Mean Residual (SRMR), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Expected Cross Validation Index (ECVI), and Model 7 was selected (Table III). According to the model fit criteria, values smaller than .08 for RMSEA and SRMR, values larger than .09 for TLI and CFA, and relatively low values for ECVI are recommended, and most of them were found to be suitable as they met the criteria (Browne & Cudeck, 1992; Hu & Bentler, 1999). Table IV showed the path coefficients of Model 7, which is the final research model in this study. The standardized path coefficients for the final research model are shown in Figure 1.

TABLE III.
Results of Model Comparison

Model	χ^2	df	TLI	RMSEA	CFI	SRMR	ECVI
1	1004.797	92	0.902	0.072	0.925	0.058	0.593
2	1012.888	98	0.908	0.070	0.925	0.058	0.591
3	1053.173	100	0.906	0.071	0.922	0.060	0.610
4	1075.336	102	0.906	0.071	0.920	0.060	0.620
5	1075.353	104	0.908	0.070	0.920	0.060	0.618
6	1078.824	106	0.909	0.070	0.920	0.061	0.618
7	1079.126	108	0.911	0.069	0.920	0.061	0.616

TABLE IV.
Results of the final research model

Path	Unstandardized coefficient	S.E.	Standardized coefficient	C.R.
PA1 → PA2	.294	.012	.345	24.788***
PA2 → PA3	.294	.012	.300	24.788***
PA3 → PA4	.294	.012	.289	24.788***
LS1 → LS2	.618	.012	.631	51.283***
LS2 → LS3	.618	.012	.678	51.283***
LS3 → LS4	.618	.012	.601	51.283***
PA1 → LS2	.018	.006	.039	3.152**
PA2 → LS3	.018	.006	.037	3.152**
PA3 → LS4	.018	.006	.035	3.152**
LS1 → PA2	.181	.025	.102	7.210***
LS2 → PA3	.181	.025	.102	7.210***
LS3 → PA4	.181	.025	.091	7.210***

Note. PA1 = physical activity level in the first year; PA2 = physical activity level in the second year; PA3 = physical activity level in the third year; PA4 = physical activity level in the fourth year; LS1 = life satisfaction level in the first year; LS2 = life satisfaction level in the second year; LS3 = life satisfaction level in the third year; LS4 = life satisfaction level in the fourth year. **p < .01, ***p < .001

The findings of the study indicate that physical activity at each time point had a positive impact on both physical activity and life satisfaction in the subsequent time point. Furthermore, physical activity at the previous time point positively influenced life satisfaction at a later time point, suggesting that greater participation in physical activity leads to improved life satisfaction. Additionally, life satisfaction at the previous time point had a

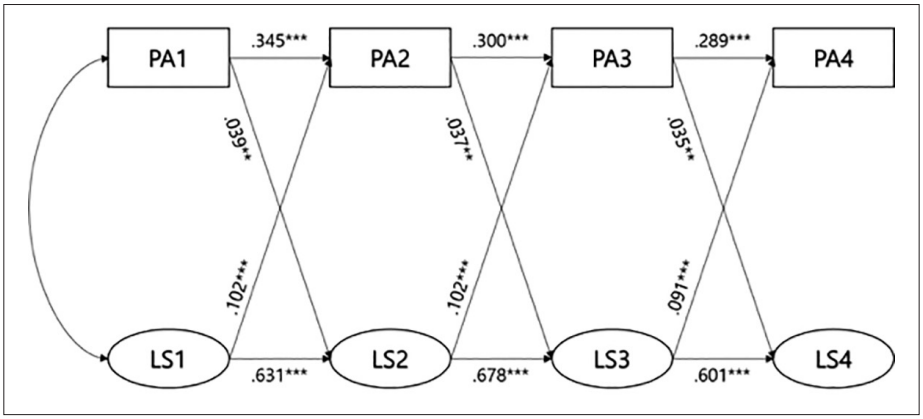

Fig. 1. - *Results of the research model.*

Note. PA1 = physical activity level in the first year; PA2 = physical activity level in the second year; PA3 = physical activity level in the third year; PA4 = physical activity level in the fourth year; LS1 = life satisfaction level in the first year; LS2 = life satisfaction level in the second year; LS3 = life satisfaction level in the third year; LS4 = life satisfaction level in the fourth year. **p < .01, ***p < .001.

positive effect on physical activity at the following point, indicating that higher levels of life satisfaction are associated with a higher likelihood of engaging in physical activity. These results demonstrate a mutual causal relationship between physical activity and life satisfaction, with the effect of life satisfaction on physical activity being greater than the effect of physical activity on life satisfaction.

Discussion

The purpose of this study was to examine the longitudinal relationship between physical activity and life satisfaction in adolescents. Previous research found a strong relationship between physical activity and life satisfaction. However, the direction of the causal relationship has remained unclear. As such, this study sought to address this gap by conducting a longitudinal analysis, which allows for a better understanding of the effective causal relationship between the two variables. The longitudinal design of the study helped overcome the limitations of previous cross-sectional studies, allowing for a more comprehensive understanding of how these variables interact and influence each other over time. By filling the gap in the existing literature and expanding the discussion, this study contributes to a better understanding of

the intricate relationship between physical activity and life satisfaction. The detailed discussion of the results of this study is as follows.

Stability of Physical Activity and Life Satisfaction

First, we found that physical activity tends to be stable over time among adolescents. In particular, the level of physical activity at a previous time point has a positive effect on the level of physical activity at subsequent time points. This result conforms to the findings of Miquelon and Castonguay's (2017)2000 study, which showed that past physical activity participation positively affects current physical activity participation, indicating the continuity in maintaining physical activity behaviors. This can be related to previous findings that past behaviors influencing future behaviors as well as repeating behaviors from the past increases the likelihood of retention for future behaviors (Albarracin & Wyer Jr, 2000; Hagger et al., 2002). However, an interesting observation from this study is that the effect of past physical activity on subsequent physical activity decreases over time. One possible explanation for this pattern is that the quality of past experiences may affect future behavior. Negative experiences, such as failure or difficulty in physical activity during childhood or adolescence, can contribute to the perception of overall inability or lack of competence in engaging in physical activity (Reynes et al., 2019).

In addition, according to Aubert et al., (2022), assessing the level of physical activity and related policies for youth across countries, South Korea's policies concerning youth physical activity received an A grade. However, the score for actual physical activity participation resulted in a D grade. South Korea ranked 37th out of 57 countries in terms of physical activity, with 26.8% of adolescents reporting experiencing depression. This could potentially lead to a decrease in individuals' resilience levels and negatively influence psychosocial resources, such as motivational factors, self-efficacy, and goal setting thereby affecting participation in physical activity (Kim et al., 2021). The decreasing trend in the effect of past physical activity on future physical activity could be attributed to the academically competitive environment in Korea, which may have led to a reduced emphasis on physical education in schools. This highlights the importance of developing curricula that foster students' interest in physical education classes and provide opportunities to experience the benefits and efficacy of engaging in physical activity. Policymakers are urged to prioritize physical education and create supportive environments that encourage students to participate in physical activities and recognize the positive impact it can have on their overall

well-being. Overall, these findings emphasize the need to consider both the continuity of physical activity behaviors and the quality of past experiences when promoting and supporting physical activity among adolescents.

Alongside physical activity, life satisfaction among adolescents tends to be stable over time. In other words, life satisfaction at a previous time point positively influences life satisfaction at subsequent time points. These results align with the study conducted by Baird et al. (2010), which observed that life satisfaction tends to remain relatively constant throughout the lifespan, with a slight decrease in older age due to health-related issues and decreased social support. Although the degree of causality did not significantly differ at each time point, the effect size of the initial measurement of life satisfaction increased from .631 to .678 and then decreased to .601 in the final measurement. This suggests that there may be other unobserved factors influencing life satisfaction. For example, the participants in this study were middle-school students who faced various stressors, including increased academic burdens as they progressed to high school. This finding is consistent with previous literature that highlights the negative impact of stress on individuals' quality of life and well-being, particularly in higher education settings (Ribeiro et al., 2018). This background is rooted in the cultural characteristics of South Korea. South Korea exhibits a fervent commitment to education, driven by rapid economic development and the proliferation of higher education opportunities. However, this trend is also associated with social challenges, including socioeconomic disparities, intense competition in standardized testing, and the financial strain of private education expenditures (Lee, 2006).

These results emphasize the complex nature of life satisfaction and the potential influence of various factors beyond the measured variables. It is important to consider the broader context and individual experiences when examining and promoting life satisfaction among adolescents. Addressing the sources of stress and providing support systems to help individuals navigate challenging transitions, such as the transition from middle school to high school, may contribute to maintaining and enhancing life satisfaction during this period of development. In sum, this study highlights the stability of life satisfaction over time among adolescents, with the influence of past life satisfaction on future life satisfaction. However, the effect size of this relationship varied, suggesting the presence of other factors that may impact life satisfaction. Future research should continue to explore these factors to gain a more comprehensive understanding of the determinants of life satisfaction in adolescents.

Longitudinal causal relationship between physical activity and life satisfaction

In addition to examining the stability of life satisfaction, we examined the effect of physical activity on life satisfaction among adolescents. The results showed that physical activity at a previous time point had a consistent and positive effect on life satisfaction at subsequent time points, with similar effect sizes observed at each time point. This supports previous research indicating that participating in physical activity enhances life satisfaction and further contributes to improved self-awareness (Stein et al., 2007). Edwards and Loprinzi (2017) conducted a study revealing that when efforts were made to regulate physical activity and induce sedentary behavior among participants, there was a decrease in life satisfaction. This finding aligns with both activity theory and need theory. Activity theory (Havighurst, 1963) suggests that life satisfaction is influenced by the frequency of engaging in various activities and the familiarity associated with them. On the other hand, need theory (Diener & Lucas, 2000) argues that life satisfaction is determined by the extent to which individuals meet their biological and psychological needs. Thus, it can be inferred that attempting to control physical activity not only fails to fulfill individual needs but also diminishes social connections, such as familiarity, resulting in a decline in life satisfaction.

Additionally, self-esteem has been identified as closely related to overall life satisfaction among adolescents (Ahmed et al., 2016). Similarly, Kleszczewska et al. (2018) found that physical activity has a positive effect on life satisfaction by enhancing self-esteem, acting as a mediating factor in this relationship. Adolescents who spend a substantial amount of time at school show that their school satisfaction positively corelates with their overall life satisfaction, with the additional engagement in physical activity amplifying this positive effect (Moral-Garcia et al., 2021). However, while physical activity inherently contributes to increased life satisfaction, participation influenced by peer pressure might diminish this effect. A more substantial impact on life satisfaction is anticipated under conditions where physical activity is intrinsically motivated by an individual (Meyer et al., 2021). These findings provide significant evidence that physical activity can contribute to increased life satisfaction among adolescents, reduce stress and depressive symptoms, and promote well-being. That is, it emphasizes the importance of incorporating physical activity programs and opportunities for adolescents, both within and outside of educational settings, to support their mental and emotional well-being. Basic psychological needs based on competence, relatedness, and autonomy play a mediating role in the process of increasing life satisfaction (Leversen et al., 2012). Accordingly, it is necessary to provide participants

with the experience of doing well through competency development opportunities and to focus on the role of contributing to the task and positive interactions between participants (Leversen et al., 2012). It is worth noting that it is critical to consider the limitations of the research design and the complexity of factors influencing life satisfaction. Thus, future research could further investigate the mechanisms through which physical activity influences life satisfaction and explore potential moderators and mediators in this relationship.

This study also uncovered that life satisfaction at a previous time point consistently affected subsequent physical activity. The effect size of this influence was found to be similar across different measurement time points. This finding contributes to the existing literature as previous research on the impact of emotional states, such as life satisfaction, on physical activity has been relatively limited compared to studies focusing on the influence of physical activity on psychological variables. For example, Jekauc and Brand (2017) highlight the influence of emotions and feelings on physical activity. They emphasize that emotional states play a crucial role in shaping individuals' engagement in physical activity. Liao et al. (2015) also provided consistent evidence indicating that positive emotional states have a significant positive impact on physical activity, while negative emotional states do not exert a significant effect. These findings align with the results of the present study, supporting the notion that positive emotions contribute to increased physical activity. Moreover, Kanning and Schoebi (2016) reported similar evidence, suggesting that positive emotions are associated with higher levels of physical activity. They also mention that incorporating emotional regulation strategies into physical activity interventions may enhance the effectiveness of such interventions in promoting physical activity. It has been shown that a positive psychological state not only provides individuals with the ability to effectively cope with various problems, but also improves the ability to mobilize social resources (Rozanski & Kubzansky, 2005). This serves as evidence that a positive psychological state acts as motivation for health promotion behavior, serving as emotional vitality on a personal level (Kubzansky & Thurston, 2007). Additionally, individuals with high life satisfaction set goals and effectively cope with difficulties as they pursue positive life outcomes, influencing psychological processes that affect health behaviors (Kim et al., 2021). Overall, the findings of this study add to the growing body of research demonstrating the influence of life satisfaction on subsequent physical activity. Emotional states, particularly positive emotions, appear to play a significant role in shaping individuals' engagement in physical activity. According to Seaton et al. (2018), positive emotions have a positive effect on physical activity and there is a mediating effect of ego resilience. The broaden-and-

build theory also posits that positive emotions build psychological resources, which gradually increase in strength over time (Fredrickson, 1998). The implications of these findings suggest that interventions targeting physical activity should consider incorporating strategies for emotional regulation alongside promoting physical activity participation.

Comprehensive View of The Results

In summary, the relationship between physical activity and life satisfaction is reciprocal, not a unidirectional relationship. Furthermore, they have a longitudinal relationship beyond their mutual relationship. However, the study yielded unexpected results contrary to the initial expectations regarding the direction of causality. While previous research has predominantly focused on the impact of physical activity on life satisfaction, this study revealed that life satisfaction has a stronger influence on predicting physical activity. In other words, the two variables continue to have a causal relationship with each other longitudinally, but life satisfaction is the stronger antecedent variable. Therefore, interventions targeting physical activity should take into account the role of life satisfaction for effectiveness.

These findings align with the study by Azevedo Da Silva et al. (2012), which found that individuals with anxiety and depressive symptoms were more likely to have low levels of physical activity. Negative emotions experienced by individuals seem to have a greater effect on physical activity participation. Additionally, Kim et al. (2015) reported that individuals with high life satisfaction tend to utilize healthcare services for preventive purposes more frequently. This suggests that life satisfaction acts as a motivating factor in adopting personal goals. When life satisfaction is low, it becomes a goal for improvement, whereas when life satisfaction is high, it becomes a process of setting and maintaining goals. Therefore, life satisfaction should be prioritized as a motivational factor that strongly influences the relationship between physical activity and life satisfaction. In addition, it is important to note that life satisfaction positively contributes to various aspects of life, including health and social relationships (Boehm & Lyubomirsky, 2008; Diener & Chan, 2011; Luhmann et al., 2013). However, the specific mechanisms underlying these relationships remain uncertain. Luhmann and Hennecke (2017) proposed that life satisfaction serves as a crucial motivational factor that influences individuals' personal environment through the adoption of personal goals. Therefore, it is possible that additional variables not considered in this study could be at play in the complex relationship between life satisfaction and physical activity. In conclusion, it has been affirmed that adolescents' engagement in numerous

physical activities significantly contributes to heightened life satisfaction. Additionally, fostering positive psychological resources, such as life satisfaction, is crucial to serve as vitality, encompassing traits like resilience and goal setting, thereby enhancing participation levels in physical activities.

Conclusion

This study makes a significant contribution by examining the longitudinal relationship between life satisfaction and physical activity. Both variables were identified as having a continuous and interdependent connection over time. The study also explored whether either variable acted as a more effective independent variable to inform targeted intervention strategies at specific time points. The findings suggest that life satisfaction plays a motivating role in shaping specific behaviors, highlighting the importance of considering life satisfaction when predicting future behavior. For the follow-up research, there is room for improvement for measuring physical activity as it was relying heavily on recollection of personal memory rather than objective and impartial methods. As the physical activity measured in this study is measured with a self-report response, an analysis through objective physical activity measurement is additionally required. In addition, it would be beneficial to explore additional or alternative variables, such as motivational factors, that may contribute to the effect of life satisfaction on physical activity. Conducting multigroup analysis considering demographic variables could also provide a more nuanced understanding of the relationship between physical activity and life satisfaction. These efforts would contribute to a better understanding of the underlying mechanisms behind the relationship between life satisfaction and physical activity.

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