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Bidirectional association between leisure time physical activity and well-being: Longitudinal evidence

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ABSTRACT

Leisure-time physical activity (LTPA) is an important means of enhancing well-being. Although previous research has typically documented the cross-sectional associations between LTPA and well-being, the longitudinal bidirectional association remains relatively unexplored. Using a latent growth curve model, this study examined the longitudinal association between the intensity of LTPA, psychological well-being, and social well-being. The results revealed that the longitudinal associations differed, depending on the intensity of the LTPA and the type of well-being. Specifically, the longitudinal associations of moderate LTPA with psychological and social well-being were bidirectional. However, psychological and social well-being at baseline directly influenced the growth of vigorous LTPA, but not conversely (i.e. vigorous LTPA at baseline → change in psychological and social well-being), indicating no bidirectional association. These findings could contribute to a better understanding of ways in which different intensities of LTPA are associated with distinct types of well-being over a long time.

KEYWORDS

Leisure-time physical activity; psychological well-being; social well-being; latent growth curve model; longitudinal study

Leisure has been acknowledged as a key path to enhancing well-being (Hood & Carruthers, 2007), given its perceived benefits such as stress reduction (Iwasaki, 2007), relation to positive emotion (Iwasaki, 2008), contribution to social connections (Glover, 2018), and development of a meaningful life (Stebbins, 2008). Within this context, leisure is regarded as an important life domain for a day-to-day sense of well-being (Lee et al., 2020).

Among various activities, leisure-time physical activity (LTPA) is a useful means to meet psychological needs and fulfill demands for intrinsic motivation, perceived freedom, and social interaction, resulting in increased psychological and social well-being (Kuykendall et al., 2015). Accordingly, the association of LTPA with psychology and social well-being has been explored in a range of disciplines, including leisure (Havitz et al., 2013), psychology (Ryan & Deci, 2001), and public health (Sylvester et al., 2012). The primary focus of previous research has centered on general LTPA, with the underlying assumption that it can directly influence and enhance well-being (Mack et al., 2012; Wiese et al., 2018). However, the association of LTPA with types of well-being can

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depend on the intensity of the LTPA (Mack et al., 2012). For example, moderate LTPA could be more associated with psychological well-being (Holstila et al., 2017) because it is likely to enhance psychological function and development (Ryan & Deci, 2001).

In this context, the directionality in a longitudinal trajectory has been emphasized (Wiese et al., 2018). The longitudinal association of LTPA with well-being is likely bidirectional because LTPA may provide the opportunity to fulfill an individual's psychosocial needs for well-being (Tinsley & Eldredge, 1995) and, reciprocally, individuals with high well-being achieved through positive LTPA experience tend to become more engaged in physical activity (Hartman et al., 2020). In this respect, such a bidirectional association may take time to develop, and it may change over time (Ku et al., 2016). Thus, longitudinal studies could provide a better understanding of ways in which LTPA could be associated with well-being over time by testing for covariance in indicators of change (Steinmo et al., 2014). While longitudinal studies have been conducted in various disciplines such as epidemiology, psychiatry, and social sciences (e.g. Ku et al., 2016; Mikkelsen et al., 2010), these have overlooked the potential bidirectional relationship between LTPA and well-being. Furthermore, intensities of LTPA (e.g. moderate, vigorous) and types of well-being (e.g. psychological, social) have also tended not to be included in the longitudinal model. This makes it difficult to assess whether LTPA at baseline is associated with growth in well-being over time and, conversely, if the initial level of well-being is related to changes in LTPA. Furthermore, potential confounders such as predispositional factors (e.g. personality traits) have rarely been considered (Kono et al., 2018; Wilson & Dishman, 2015).

To fill these gaps, we aim to elucidate the longitudinal association between LTPA and well-being. Specifically, this study examines the potential influence of LTPA intensity (moderate and vigorous) at baseline on changes in a specific dimension of well-being (psychological and social) trajectories over time, and, conversely (well-being at baseline → changes in LTPA). We also seek to identify the effect of key personality traits in the longitudinal association. Based on nationally representative data on adults from the Midlife Development in the U.S. (MIDUS) study, this research expands the current understanding of the longitudinal directionality of the relationship between intensities of LTPA and types of well-being in a time sequence. Accordingly, the following research questions (RQs) were formulated and assessed:

- RQ1: How are LTPA at baseline associated with changes in well-being over time, and, conversely (i.e. well-being at baseline → changes in LTPA), considering the intensity of LTPA (e.g. moderate, vigorous) and a specific dimension of well-being (e.g. psychological, social)?
- RQ2: What personality traits influence the initial level of and changes in different intensities of LTPA (e.g. moderate, vigorous), psychological well-being, and social well-being over time?

Literature review

Eudaimonic well-being theory

Well-being is regarded as a multifaceted concept and has been examined primarily in two research streams: a hedonic view of subjective well-being (Diener & Ryan, 2009) and a eudaimonic view of psychological and social well-being (Keyes, 1998). In the

hedonic approach, well-being is conceptualized as maximizing pleasure and avoiding pain, which is reflected in research on subjective well-being (Diener & Ryan, 2009). A pleasurable experience is likely to be more associated with life satisfaction in the short term (Oishi et al., 2001). In contrast, the eudaimonic approach defines well-being as fulfilling the psychological needs that support human flourishing (Ryff & Singer, 2000), which is linked with research on psychological and social well-being (Keyes et al., 2002). Thus, eudaimonic well-being is characterized by meaning in life, social connectedness, and personal growth with self-realization through the opportunity to fulfill one's inner potential and self-concordant goals (Ryan et al., 2008). From the eudaimonic well-being perspective, human flourishing is related to living in truth with oneself as a worthwhile human being, contributing to enhanced vitality and self-determination (Ryff & Singer, 2000). Eudaimonic motivation can steer engagement with eudaimonic activities as individuals seek meaning in life and self-realization (Ryan & Deci, 2001). This process leads to personal growth, which is a core dimension of eudaimonic well-being (Kimiecik, 2016). According to the self-determination theory (SDT), eudaimonic well-being could be achieved by engaging in activities that fulfill psychological needs (e.g. autonomy, competence, and relatedness; Ryan et al., 2008). For example, building a positive relationship with others in eudaimonic activity could be a resource for increasing well-being. As people build the resources to fulfill psychological needs through eudaimonic activity, they are likely to feel meaningful and purposeful in life and would try to sustain it (Steger et al., 2008). Thus, the greater involvement with eudaimonic activity likely has more enduring well-being (Ryan et al., 2008). In addition, some activities may require a higher level of skills or may be more challenging than others. Due to such differences in activity characteristics, engaging in a certain activity could be related to personal value or personality traits (Huta & Waterman, 2014).

Given the eudaimonic approach to well-being, scholars in positive psychology have suggested that the functional benefits of eudaimonic well-being could be greater than those of hedonic well-being (Zuo et al., 2017). For example, the function of hedonic well-being is considered life satisfaction (Diener & Ryan, 2009), whereas the function of eudaimonic well-being encompasses multilateral aspects such as a meaningful life, personal growth, and social integration, which are constructions of psychological and social well-being (Ryff & Singer, 2008). Thus, eudaimonic well-being is associated with positive sociopsychological functioning that leads to a meaningful life with personal growth. Unlike hedonic well-being, which involves present-oriented needs (e.g. pleasure and positive affects) regarding satisfaction in the short term, eudaimonic well-being integrates intrinsic goals and social values in the past, present, and future (Steger et al., 2008).

LTPA and eudaimonic well-being

LTPA refers to a collection of behaviors that require the expenditure of energy during discretionary times (Berg et al., 2015). Unlike other types of physical activity (PA; e.g., domestic, transport, and occupational), LTPA is connected to self-realization, growth, and development in the satisfaction of innate psychological needs (Lloyd & Little,

2010). LTPA also provides individuals with opportunities for social connection with others, which contributes to the flourishing of their social life (Lotan et al., 2005). Thus, LTPA can be hypothesized as a variable to enhance psychological and social well-being by optimizing eudaimonic functioning. Accumulating evidence suggests an association between LTPA and psychological and social well-being (Berlin & Klenosky, 2014; Hartman et al., 2020; Wankel & Berger, 1990). Lloyd and Little (2010) found that psychological well-being could be enhanced by developing a sense of competence, autonomy, and social interaction through LTPA experience. Wankel and Berger (1990) noted that LTPA provided individuals with opportunities for personal growth, social change, and social interaction in relation to social well-being. Furthermore, socialization is a key value of engagement in LTPA, rousing future intentions to participate in LTPA (Berlin & Klenosky, 2014). Thus, increased engagement in LTPA is associated with greater psychological and social well-being (Mack et al., 2012). Psychological and social well-being could also be predictors of engagement in LTPA. People with optimized psychological and social well-being are more likely to engage in LTPA to fuel and refuel well-being continuously (Kimiecik, 2016). As Ryan et al. (2009) noted, eudaimonic motivations to satisfy basic psychological needs predict engagement in LTPA. If psychological and social well-being are enhanced by fulfilling psychological needs, individuals can continually engage in LTPA for their well-being. Kimiecik (2016) also noted that engagement in health behaviors such as LTPA may occur when individuals focus on eudaimonic well-being through the satisfaction of psychosocial needs. Thus, LTPA and well-being could be predictors of each other, which indicates a bidirectional relationship.

Intensity of LTPA and eudaimonic well-being

In the LTPA – well-being relationship, the intensity of LTPA could be an important variable because the effect of LTPA on psychological and social well-being may vary and depends on intensity (e.g. moderate, vigorous; Kekäläinen et al., 2020). Intensity in this context is the rate of oxygen consumption during PA, usually measured by the metabolic equivalent (MET), which represents the rate of oxygen consumption by the body at rest (e.g. moderate: 3.0–6.0 METs; vigorous: >6.0 METs; U.S. Department of Health and Human Services [DHHS], 2008). Given the criteria of PA intensities, moderate LTPA requires a moderate amount of effort, but an individual can still talk while engaging in moderate activity, such as brisk walking, yoga, or aqua aerobics. Conversely, vigorous LTPA requires a large amount of physical effort, and an individual may find it difficult to say more than a few words during such activity. Examples of vigorous LTPA include competitive basketball, soccer, and mountain climbing (U.S. Department of Health and Human Services [DHHS], 2008). LTPA choice could depend on the motivation and intensity of LTPA. For example, older people tend to choose LTPA they can easily participate in, which provides an opportunity to fulfill their physical and psychological needs (Tinsley & Eldredge, 1995). Thus, moderate LTPA, such as brisk walking, may be more attractive for older people than vigorous LTPA that requires high-performance skills and physical ability. In contrast, when seeking to acquire special skills, achieve goals, and gain physical strength, young people may participate in vigorous LTPA requiring competition, high-performance skills, and self-

regulation goals (e.g. competitive sports; Berlin & Klenosky, 2014). From the eudaimonic well-being standpoint, eudaimonic motivations to participate in a certain LTPA can be associated with its level of intensity, which may connect with the dimensions of psychological and social well-being. Accumulated evidence in neuroscience and physiology indicates that different intensities of LTPA can be related to distinct dimensions of well-being differently (Katona & Freund, 2008; Raichlen et al., 2013). Neurobiologically, the level of LTPA intensity is linked with a sense of well-being, improved affect, and reduced anxiety (Raichlen et al., 2013). For example, moderate LTPA is related to neurobiological effects that improve mental well-being by releasing endocannabinoids from neurons in an activity-dependent manner (Katona & Freund, 2008). Endocannabinoids contribute to PA outcomes in a psychological state that includes induced motivation to engage in PA (Dietrich & McDaniel, 2004). Given the neurobiological effect of PA, the greatest effect on mental well-being occurs at a medium level of PA intensity (Berger & Motl, 2000), whereas the lowest and highest intensity levels are less effective because they release fewer endorphins (Costigan et al., 2019). Physiologically, the most vigorous PA could be related to negative effects and poor mental well-being, caused by overtraining, stress, and injury (Armstrong & Vanheest, 2002). By contrast, vigorous PA may influence the improvement of fitness and body shape that results in an improved physical self-concept and improved self-efficacy over time (Costigan et al., 2019).

Personality, LTPA, and eudaimonic well-being

Personality refers to differences between individuals or long-standing traits of thoughts, feelings, and behaviors (Rhodes & Smith, 2006). Given the common connection between traits and particular behaviors in life domains (Barnett, 2013), personality is related to leisure activities such as LTPA that require movement and energy expenditure (Rhodes & Boudreau, 2017). Because various personality traits can influence individuals' perceptions of and reactions to various stimuli, certain dimensions of personality are associated with engagement in PA (Rhodes & Smith, 2006). In applying the five-factor model (FFM) for personality traits, scholars have noted that the effect of personality on PA is more pronounced in vigorous than in light or moderate PA (Rhodes & Boudreau, 2017). The FFM consists of five main traits: neuroticism, extraversion, openness, agreeableness, and conscientiousness. Specifically, extraversion, conscientiousness, and neuroticism have been found to be strongly related to the particular intensity of PA (Rhodes & Pfaeffli, 2012). For instance, extraversion and conscientiousness are positively linked with engagement in vigorous PA, whereas neuroticism is negatively related to vigorous PA (Box et al., 2019). Furthermore, a 40-year longitudinal study showed that high extraversion and low neuroticism are also predictors of changes in participation in PA over time (Kern et al., 2010). The five personality traits are also related to dimensions of psychological well-being. Specifically, as noted by Schmutte and Ryff (1997), personality traits are related to dimensions of psychological well-being that include self-acceptance, environmental mastery, and life purpose. Openness is related to personal growth, low neuroticism is associated with autonomy, and agreeableness and extraversion are linked to positive relations with others, a dimension of social well-being. Collectively, the

findings of previous studies suggest that stable individual differences such as personality traits are important factors for well-being, given the correlation of personality and well-being (Fogle et al., 2002; Sato et al., 2018).

Methods

Data collection

The dataset is from a nationally representative sample of middle-aged Americans surveyed as part of the MIDUS. The data focus on a three-wave longitudinal study (Wave 1: 1995–1996; Wave 2: 2004–2006; Wave 3: 2013–2014) with behavioral, social, and psychological factors that influence health and well-being (Radler & Ryff, 2010). The first wave of MIDUS collected data via a 30-minute phone interview followed by mail-returned and self-administered questionnaires. A total of 7,108 individuals participated during this phase (ages: 24–75 years; $M = 46.40$; $SD = 13.00$; education level: 13.21 years; males: 48.3%; females: 51.7%; Brim et al., 2004). Similarly, about 10 years later, data collection was conducted for Wave 2 of MIDUS. After adjustment for mortality, it retested 70% of the participants from Wave 1 ($N = 4,963$) between 2004 and 2006 (ages: 35–86 years; $M = 55.40$, $SD = 12.45$; education level: 14.24 years; male: 46.2%; female: 53.8%). Accordingly, about 9 years later MIDUS Wave 3 was conducted with 67% of MIDUS Wave 2 respondents ($N = 3,294$), adjusted for mortality in 2013–2014 (age: 42–92 years; $M = 64.30$, $SD = 11.20$; education level: 14.68 years; male: 44.8%; female: 55.2%). Data for Wave 3 were also collected through personal interviews with subsequent mail-returned questionnaires.

Measures

LTPA

Participation at different intensities of LTPA was measured using the following questions from all three waves: for moderate LTPA participation: "How often do you engage in moderate PA that is not physically exhausting but causes your heart rate to increase slightly and works up a sweat (e.g. light tennis, slow or light swimming, low-impact aerobics, golfing without a power cart)?" and for vigorous LTPA participation: "How often do you engage in vigorous PA that causes your heart to beat so rapidly that you can feel it in your chest, for long enough that you work up a good sweat and are breathing heavily (e.g. competitive sports like running, vigorous swimming, high-intensity aerobics)?" Separate responses were requested for the summer and winter to account for seasonal variations in LTPA participation (i.e. two moderate LTPA questions and two vigorous LTPA questions). A 6-point scale was used for all items (1 = several times a week or more; 6 = never), and the items were reverse-coded. Subsequently, average scores for moderate and vigorous LTPA based on the summer and winter for each wave were computed.

Well-being

The variables included psychological and social well-being for Waves 1–3. Psychological well-being consisted of six dimensions: autonomy, environmental mastery, personal growth, positive relations with others, purpose in life, and self-acceptance (Ryff & Keyes, 1995). Participants were asked to report their level of agreement with statements regarding psychological well-being on a 7-point scale (1 = strongly agree; 7 = strongly disagree). The items were reverse-coded. Two versions measured psychological well-being: for Wave 1, an 18-item version indexed in six dimensions was employed, and an additional 24-item version was used for Waves 2 and 3. In this study, we used the 18-item version to ensure the consistency of measured items during each wave.

Social well-being comprised 14 items indexed in five dimensions: meaningfulness of society, social integration, acceptance of others, social contribution, and social actualization (Ryff & Keyes, 1995). Participants were asked to report their level of agreement with statements concerning social well-being on a 7-point scale (1 = strongly agree; 7 = strongly disagree). The items were reverse-coded to reflect higher standing in the scale.

Personality traits

Personality traits were operationalized with 25 items within five dimensions: neuroticism, conscientiousness, extraversion, openness, and agreeableness (Schmutte & Ryff, 1997). Neuroticism comprised subdomains such as moody, nervous, worrying, and calm. Conscientiousness was composed of the subdomains organized, hardworking, careless, and responsible. Extraversion consisted of outgoing, friendly, lively, talkative, and active. Openness encompassed creative, adventurous, broad-minded, intelligent, imaginative, curious, and sophisticated. Agreeableness comprised warm, helpful, sympathetic, and caring. For each trait, participants were asked to report their level of agreement with statements on a 4-point scale (1 = not at all; 4 = a lot). In this study, we created trait scores based on the average noted in each dimension.

Control variables

Several variables were included to account for potential effects on the relationship between LTPA and well-being: age, gender, educational level, income, marital status, physical health, mental health, chronic condition, and neighborhood environment (Floyd et al., 2008; Lee et al., 2018). All covariates at baseline were included in the models. We converted gender (male = 0, female = 1) and race (White = 1, other = 0) into dummy variables. We coded health-related variables on a scale ranging from 1 (poor) to 5 (excellent). Figure 1 illustrates the analysis plan for this study.

Statistical analysis

Preliminary analyses

Of the 7,124 panel members compiled as the baseline during Wave 1, 4,955 individuals responded during Wave 2. A total of 3,294 participants from Wave 2 were included in

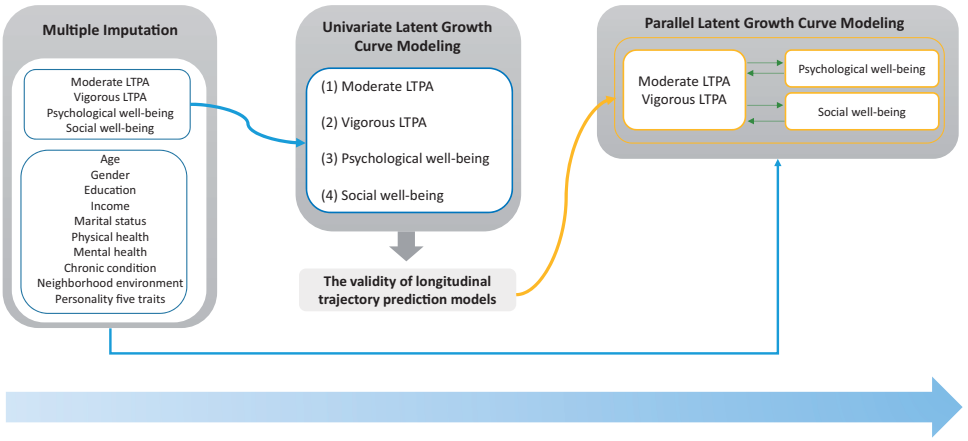

Figure 1. Study design.

Wave 3. Of the 3,294 respondents, only 1,627 had complete data. Thus, multiple imputations were conducted to address missing values. Multiple imputations under a missing value with random assumptions employed plausible values instead of missing values, which reduced the bias of the estimate (Dong & Peng, 2013). Multivariate imputations by chained equations can be a useful tool to deal with data sets that include large numbers of incomplete variables, which are difficult to use to determine adequate joint distribution. In addition, the imputation process can handle categorical and ordinal variables (Royston & White, 2011). All variables were included in the imputation process to create 25 imputed datasets with 10 iterations. These imputed estimates were merged into a composite one. A large number of imputations (e.g. at least 20) can reduce sampling variability more efficiently, especially for a large amount of missing data (Sterne et al., 2009). The descriptive statistics, internal consistency, and correlations for the baseline appear in Table 1.

Latent growth curve modeling (LGCM)

A LGCM statistical technique based on structural equation modeling was employed to examine longitudinal change over time and to assess the association between the intensity of LTPA and the type of well-being. Generally, LGCM allows researchers to examine the association between an initial status at baseline (intercept) and the rate of change (slope; e.g. an individual who begins with good physical health and shows better physical health over time; Brailean et al., 2017).

Following Duncan and Duncan (2009), a parallel LGCM was conducted in a step-sequential approach. First, we specified four univariate LGCMs (without covariates) to measure change over time in the focal constructs (e.g. LTPA and well-being). It happens that LGCM has two latent variables, one for the intercept (status at baseline) and one for the slope (rate of change across a wave) with random effects to capture between-individual difference and within-individual change. Unlike in usual structural equation modeling, the factor loadings were all constrained to a value of 1 for the intercept because the intercept yields information about the mean and variance of the individual

Table 1. Descriptive statistics, reliability, and correlations among primary variables ($N = 3{,}294$).

Time	Variables	M	SD	Cronbach's α	Imputed ratio	1	2	3	4	5	6	7	8	9	10	11	12
Wave 1	1. Moderate LTPA	5.38	0.91	0.88	0.11	1											
	2. Vigorous LTPA	4.13	1.62	0.86	0.15	0.46**	1										
	3. PWB	5.64	0.75	0.75	0.10	0.16**	0.14**	1									
	4. SWB	4.69	0.92	0.72	0.17	0.11**	0.11**	0.53**	1								
Wave 2	5. Moderate LTPA	4.15	1.73	0.95	0.12	0.30**	0.33**	0.13**	0.12**	1							
	6. Vigorous LTPA	3.43	1.85	0.94	0.15	0.25**	0.36**	0.11**	0.12**	0.66**	1						
	7. PWB	5.60	0.78	0.79	0.11	0.13**	0.10**	0.47**	0.63**	0.13**	0.11**	1					
	8. SWB	4.57	0.89	0.74	0.11	0.13**	0.14**	0.65**	0.48**	0.16**	0.15**	0.56**	1				
Wave 3	9. Moderate LTPA	4.10	1.78	0.95	0.17	0.28**	0.37**	0.12**	0.13**	0.40**	0.41**	0.16**	0.13**	1			
	10. Vigorous LTPA	3.40	1.91	0.96	0.15	0.22**	0.36**	0.10**	0.12**	0.35**	0.46**	0.14**	0.10**	0.65**	1		
	11. PWB	5.51	0.76	0.77	0.11	0.18**	0.15**	0.45**	0.60**	0.20**	0.19**	0.55**	0.65**	0.25**	0.23**	1	
	12. SWB	4.50	0.90	0.74	0.11	0.14**	0.11**	0.56**	0.41**	0.18**	0.17**	0.65**	0.45**	0.18**	0.17**	0.63**	1

Note. Wave 1: MIDUS 1(1995–1996); Wave 2: MIDUS 2(2004–2006); Wave 3: MIDUS 3(2013–2014); LTPA: leisure-time physical activity; PWB: psychological well-being; SWB: social well-being $^{**}p < .01$.

intercepts at the point of origination. The first and last slope factor loadings (Wave 1 and Wave 3) for the nonlinear model were constrained to 0 and 1, and the second slope factor loading was freely estimated to reflect growth over time (Duncan & Duncan, 2009). Furthermore, the intercept and slope were allowed to covary to evaluate the degree to which the slope of changes was related to the initial point of origination for each individual. To better understand the general LGCM model, Equation (1) is noted:

$$y_{\mathrm{it}} = \alpha_i + \lambda_t \beta_i + \varepsilon_{\mathrm{it}} \tag{1}$$

where y_{it} denotes the value of trajectory variable y for the ith case at time t, α_i is the random intercept for case i, λ_t represents the numeric value of time at time t, β_i is the random slope for case i, and ε_{it} represents the disturbance for the case i at time t. Because the intercept and slope were allowed to vary randomly within the group of individuals, the equations for the intercept and slope were as follows:

$$\alpha_i = \mu_\alpha + \zeta_{\alpha i} \tag{2}$$

$$\beta_i = \mu_\beta + \zeta_{\beta i} \tag{3}$$

where μ_α and μ_β represented the mean intercept and mean slope across all cases (fixed), and $\zeta_{\alpha i}$ and $\zeta_{\beta i}$ were disturbances in the deviations of intercepts and slopes from the means across cases (random).

Second, parallel latent growth models were used to determine whether an initial statue in one domain predicted change in a different domain. Variables at baseline (e.g. demographics and personality traits) were further included as predictors of the intercept and slope. Based on the intensity of LTPA and the type of well-being, two models were developed: Model 1: moderate–vigorous LTPA and psychological well-being; Model 2: moderate–vigorous LTPA and social well-being. Figure 2 presents the model of parallel LGCM in this study. For the model fit indices, we used the comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square error of approximation (RMSEA), and the chi-square goodness of fit test to assess the suitability of the model. These measures are typically used to assess model fit because the sample size influences the $\chi 2$ value. Recent longitudinal studies have also generally included CFI, TLI, and RMSEA (Li et al., 2014). The following cutoff values for acceptable model fit were used: CFI and TLI values greater than 0.95 and RMSEA values smaller than 0.05 (Kline, 2016).

Results

Univariate LGCM

This study consisted of two phases, using Amos 25.0 with maximum likelihood estimation. The first phase of the analysis comprised univariate LGCM. Based on the mean score for LTPA (moderate and vigorous) and well-being (psychological and social well-being) as well as growth trajectory estimates, an unconditional nonlinear LGCM was conducted to assess the slope of changes. All unconditional models had an acceptable fit: moderate LTPA (χ^2 (2)=1.82, p<.001, CFI = 0.99, TLI = 0.99, RMSEA = 0.01, 90% CI [0.00, 0.49]), vigorous LTPA (χ^2 (2)=1.56, p<.001, CFI = 0.98, TLI = 0.98, RMSEA = 0.01, 90% CI [0.00, 0.47]), psychological well-being (χ^2 (2) = 9.77, p<.001, CFI =

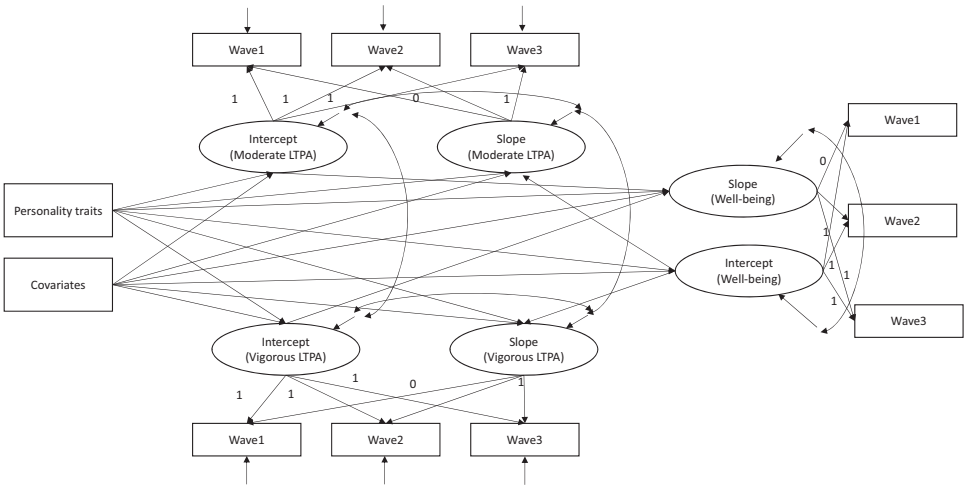

Figure 2. The models of Parallel LGCM. *Note*. Based on the modification indices, residual error variances were correlated as follows: (a) intercepts of moderate and vigorous LTPA; (b) slopes of moderate and vigorous LTPA; (c) intercept and slope of moderate LTPA (d) intercept and slope of vigorous LTPA; and (e) intercept and slope of psychological and social well-being.

0.99, TLI = 0.99, RMSEA = 0.06, 90% CI [0.03, 0.08]), and social well-being (χ^2 (2)=1.11, p<.001, CFI = 0.97, TLI = 0.96, RMSEA = 0.01, and 90% CI [0.00, 0.42]).

The unconditional LGCM analysis indicated that the means of the intercepts for moderate LTPA (M = 5.38), vigorous LTPA (M = 4.13), psychological well-being (M = 5.64), and social well-being (M = 4.69) were significant and high at p<.001. The means of the slopes for moderate LTPA (M= −0.63), vigorous LTPA (M= −0.84), and psychological well-being (M= −0.12) were also significant at p<.001, whereas the slope in social well-being was not significant. The findings indicated that people were highly engaged in moderate and vigorous LTPA at baseline, followed by a negative and significant decline over time. Similarly, psychological well-being was high at baseline but slightly declined over time. However, the growth in social well-being stayed at the same level as it was at baseline. The variance of growth for moderate and vigorous LTPA was significant and indicated individuals exhibited variability in their growth change ($\text{Var}_{\text{Moderate}}$ = .736, SE = .10, p < .001; $\text{Var}_{\text{Vigorous}}$ = .300, SE = .12, p < .01), whereas the variance of growth rates for psychological and social well-being was not significant. Additionally, the covariance between the intercept and slope for moderate and vigorous LTPA was significant. Essentially, an increase in initial moderate and vigorous LTPA participation resulted in greater change over time ($\text{Cov}_{\text{Moderate}}$=1.491, SE = 0.60, p<.001; $\text{Cov}_{\text{Vigorous}}$=0.271, SE = 0.047, p<.05). However, the covariance between the intercept and slope for psychological and social well-being was not significant.

The freely estimated factor loading for the slope of moderate LTPA in Wave 2 was 0.39, indicating that 39% of the total decline in moderate LTPA occurred between Wave 1 and Wave 3. Likewise, the freely estimated factor loading for the slope of vigorous LTPA in Wave 2 was 0.29, which indicated that 29% of the total decline in vigorous LTPA occurred between Wave 1 and Wave 3. The freely estimated factor for the slope of psychological well-being was 0.76, indicating that 76% of the total decline occurred between Wave 1 and

Table 2. Standardized parameter estimates of univariate LGCM.

	Intercept		Slope	
Variable	M (*SE*)	$\sigma 2$ (*SE*)	M (*SE*)	$\sigma 2$ (*SE*)
Moderate LTPA	5.38*** (0.27)	0.67*** (0.07)	−0.63*** (0.02)	0.73***(0.10)
Vigorous LTPA	4.13*** (0.45)	0.85*** (0.11)	−0.84***(0.02)	0.30** (0.12)
Psychological WB	5.64*** (0.01)	0.40*** (0.02)	−0.12***(0.01)	0.03 (0.01)
Social WB	4.69*** (0.02)	0.57*** (0.03)	−0.01 (0.01)	0.05 (0.01)

Note. Intercept represents baseline, Slope represents growth rate; all of the intercept parts were fixed at 1; slope factors were fixed at 0, 1, and freely; **$p<.01$; ***$p<.001$.

Wave 3. Finally, the freely estimated factor loading for the slope of social well-being was 0.10, showing that 10% of the total decline occurred between Wave 1 and Wave 3. Table 2 presents standardized parameter estimates for the univariate LGCM.

Conditional parallel LGCM

The second phase of the analysis involved conditional parallel LGCM (RQ1 and RQ2). Based on the above unconditional LGCM, we created two parallel LGCMs to assess whether one variable at baseline was related to growth in the others, which included predictors for examining their effect on the change in growth.

Model 1. moderate–vigorous LTPA and psychological well-being

The model fit of the parallel LGCM for moderate to vigorous LTPA and psychological well-being was acceptable: $\chi 2$ (68)=6.94, $p<.001$, CFI = 0.97, TLI = 0.96, and RMSEA = 0.05 with 90% CI = [0.04, 0.05]. As shown in Table 3, the findings revealed that the baseline level of moderate LTPA was positively associated with growth in psychological well-being ($\beta = 0.248$, $p<.001$). Likewise, the baseline level of psychological well-being was positively related to growth in moderate LTPA ($\beta = 0.073$, $p<.01$), indicating that the longitudinal relationship between moderate LTPA and psychological well-being could be bidirectional. However, the baseline level of vigorous LTPA was not significantly associated with growth in psychological well-being, whereas the baseline level of psychological well-being was positively related to growth in vigorous LTPA ($\beta = 0.172$, $p<.001$). The results indicated that the initial level of psychological well-being led to an increase in vigorous LTPA over time, though we found no effect of vigorous LTPA on psychological well-being.

With respect to personality traits, openness was significantly related to the baseline level of moderate LTPA ($\beta = 0.094$, $p<.001$), vigorous LTPA ($\beta = 0.101$, $p<.001$), and psychological well-being ($\beta = 0.127$, $p<.001$) as well as growth in vigorous LTPA ($\beta = 0.061$, $p<.05$) and psychological well-being ($\beta = 0.098$, $p<.001$). Extraversion was significantly associated with the baseline level of vigorous LTPA ($\beta = 0.096$, $p<.001$) and psychological well-being ($\beta = 0.236$, $p<.001$), along with growth in vigorous LTPA ($\beta = 0.111$, $p<.001$) and psychological well-being ($\beta = 0.202$, $p<.001$). The results indicated that openness and extraversion could be predictors for growth in vigorous LTPA and psychological well-being. All personality traits were significantly associated with the initial level of and growth in psychological well-being (Table 3).

Model 2: moderate–vigorous LTPA and social well-being

The model fit of the parallel LGCM for moderate to vigorous LTPA and social well-being indicated an adequate fit: $\chi 2(68) = 6.58$, $p<.001$, CFI = 0.97, TLI = 0.96, and RMSEA = 0.04 with 90% CI = [0.04, 0.05]. The results revealed that the baseline level of moderate LTPA was positively related to growth in social well-being ($\beta = 0.170$, $p<.001$). Also, social well-being at baseline influenced growth in moderate LTPA ($\beta = 0.117$, $p<.001$). The results indicated that a bidirectional association between moderate LTPA and social well-being may occur over time. Similar to Model 1, in Model 2, the baseline level of vigorous LTPA was not significantly associated with growth in social well-being, whereas the baseline level of social well-being was positively associated with growth in vigorous LTPA ($\beta = 0.165$, $p<.001$). The results demonstrated that a higher level of social well-being at baseline led to positive change in vigorous LTPA over time, but not conversely (i.e. vigorous LTPA at baseline → change in social well-being).

Among the personality traits, agreeableness was negatively associated with moderate LTPA (β=-0.059, $p<.05$), but other associations were not significant. However, the growth in vigorous LTPA was significantly related to extraversion ($\beta = 0.135$, $p<.001$) and openness ($\beta = 0.062$, $p<.05$). Growth in social well-being was significantly related to extraversion ($\beta = 0.173$, $p<.001$) and conscientiousness ($\beta = 0.063$, $p<.05$). The results showed that change in vigorous LTPA and social well-being over time could be associated with specific personality traits. Table 3 presents standardized parameter estimates and R-squared values for the univariate LGCM.

Discussion

Based on nationally representative data, this research contributes to the understanding of the longitudinal association between intensities of LTPA and types of well-being. Although scholars generally agree on the directional effect of LTPA on well-being (Holstila et al., 2017), the association is more complex than is often implied in the literature and deserves greater interpretation (Sylvester et al., 2012). Hence, this study revealed (a) how LTPA intensities at baseline were associated with change in psychological and social well-being and vice versa (i.e. well-being at baseline → changes in LTPA); and (b) how personality traits were linked to the baseline level and change in different levels of LTPA, psychological well-being, and social well-being.

The results from the parallel LGCM indicated that moderate LTPA at baseline was related to growth in psychological well-being over time, and vice versa. Individuals with higher moderate LTPA at baseline were more likely to show a fast increase in psychological well-being. Also, those with greater psychological well-being at baseline were more likely to engage in moderate PA over time. These results are in line with those of previous studies indicating that LTPA and well-being could be predictors of each other (Kimiecik, 2016; Saunders et al., 2018). Psychological well-being could be strengthened even by moderate LTPA, providing an opportunity for self-development, personal growth, and satisfaction of psychological needs (Lloyd & Little, 2010). Although it is not the primary interest of this study, positive psychological functioning gained by moderate LTPA might become a critical factor in the longitudinal association. As people

Table 3. Standardized Parameter Estimates in LGCM.

	Model 1						Model 2					
	Moderate LTPA		Vigorous LTPA		Psychological WB		Moderate LTPA		Vigorous LTPA		Social WB	
	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope
Moderate LTPA ITC						0.248***						0.170***
Vigorous LTPA ITC						0.035						0.035
Psychological WB ITC		0.073**		0.172***								
Social WB ITC								0.117***		0.165***		
R-squared	0.089	0.115	0.188	0.153	0.356	0.387	0.101	0.106	0.194	0.170	0.442	0.365
Agreeableness	−0.002	−0.063*	−0.064**	−0.046	0.072**	−0.138***	−0.004	−0.059*	−0.064**	−0.033	0.029	−0.024
Extraversion	0.012	−0.055	0.096***	0.111***	0.236***	0.202***	0.014	−0.051	0.105***	0.135***	0.130***	0.173***
Neuroticism	0.028	0.011	0.038	0.037	−0.396***	−0.437***	0.024	0.019	0.035	0.045	−0.282***	−0.037
Conscientiousness	0.058*	−0.035	0.025	−0.029	0.168***	0.062**	0.057*	−0.020	0.026	−0.007	0.017	0.063*
Openness	0.094***	0.043	0.101***	0.061*	0.127***	0.098***	0.094***	0.037	0.081***	0.062*	0.140***	−0.018
Age	−0.086***	−0.152***	−0.148***	−0.195***	−0.039	0.075**	−0.100***	−0.151	−0.154***	−0.197***	0.015	−0.031
Gender	0.016	−0.074**	−0.245***	0.218***	0.012	0.025	0.015	−0.070	−0.253***	0.243***	0.005	0.062*
Education	0.067**	0.080***	0.014	0.126***	−0.014	0.126***	0.070**	0.071**	0.015	0.114	0.089***	0.175***
Income	−0.022	−0.078**	−0.017	−0.059*	−0.009	−0.130***	−0.023	−0.077**	−0.017	−0.063	−0.006	−0.091***
Marital status	−0.019	0.031	0.022	−0.041	−0.085***	0.017	−0.021	0.024	0.025	−0.062	−0.009	0.001
Physical health	0.178***	0.035	0.189***	−0.028	0.001	0.027	0.190***	0.033	0.192***	−0.081***	0.062**	0.016
Mental health	0.028	−0.024	0.002	0.008	0.185***	0.186***	0.027	−0.017	−0.002	0.030	0.076**	0.135***
Chronic condition	0.013	−0.050*	−0.041	−0.032	−0.064**	−0.027	0.014	−0.050*	−0.041	0.026	−0.035	0.028
Neighborhood EV	0.056*	−0.002	0.064**	0.062*	0.153***	0.091***	0.068**	0.027	0.067**	0.101***	0.318***	0.411***

Note. ITC: Intercept representing baseline; slope: growth rate; *$p<.05$; **$p<.01$; ***$p<.001$.

get older, their physical ability tends to decrease, which could become a barrier to engagement in vigorous LTPA (Tinsley & Eldredge, 1995). Thus, from a longitudinal perspective, moderate LTPA could be more useful for satisfying individuals' psychological needs over time than vigorous LTPA.

The longitudinal association between moderate LTPA and social well-being is bidirectional. Consistent with the results of prior studies (McAuley et al., 2000; Stathi et al., 2002), the findings of the current study indicate that moderate LTPA at baseline is related to growth in social well-being and vice versa (i.e. social well-being at baseline → changes in moderate LTPA). Thus, perceived flourishing in one's social life could be enhanced by moderate LTPA over time, providing opportunities for positive social benefits such as social interaction and interpersonal relationships (Dionigi & Lyons, 2010). According to the eudaimonic approach to well-being, the social nature of moderate LTPA (e.g., a walking group) may play a role in enhanced social well-being (Sylvester et al., 2012). It is noteworthy that engagement in moderate LTPA is more related to social well-being in the long term, which may provide a better opportunity for social connectedness than different domains of PA (e.g. occupational PA; Cerin et al., 2009). In addition, the degeneration of physical ability over time may cause individuals to continuously engage in moderate LTPA rather than vigorous LTPA in the long term. Thus, moderate LTPA may be a useful resource for fulfilling the dimensions of social well-being, from a longitudinal perspective. By contrast, the association of vigorous LTPA with psychological and social well-being was not bidirectional. Vigorous LTPA at baseline was not related to growth in psychological and social well-being, whereas psychological and social well-being at baseline were associated with the change in vigorous LTPA over time. The findings are inconsistent with previous studies indicating that individuals with vigorous LTPA were more likely to report greater mental health (Bray & Born, 2004; Harbour et al., 2008) and social benefit (VanKim & Nelson, 2013). This might be because this study focused on the longitudinal association. The characteristics of vigorous LTPA require high oxygen consumption and a large amount of physical effort (DHHS, 2008). Thus, vigorous LTPA may be more associated with physical health in the long term (Costigan et al., 2019) rather than psychological and social well-being. From characteristics of activity standpoint, vigorous LTPA may also require a high level of skill and challenge (e.g. tennis and climbing). Given that such activity characteristics can deliver the greater satisfaction of psychological needs and then develop sustainable well-being (Steger et al., 2008), people with a high psychological and social well-being, seeking to sustain their well-being in the long term, are likely to engage in vigorous LTPA more frequently over time.

Another finding of this study is the association of personality traits with the intensity of LTPA and type of well-being. Although the personality traits examined were mostly not associated with moderate LTPA, except for agreeableness, growth in vigorous LTPA was commonly related to extraversion and openness in both models (psychological and social well-being). The finding is in line with those of previous studies showing that the association of personality traits with PA is more pronounced for vigorous than for moderate activity (Rhodes & Pfaeffli, 2012; Rhodes et al., 2007). Furthermore, certain traits promote the development of specific virtues (Ozer & Benet-Martinez, 2006). For example, extraversion and openness are more associated with inspiration, which can enhance engagement

in vigorous LTPA (Rhodes & Pfaeffli, 2012). Interestingly, growth in psychological well-being was significantly associated with all personality traits, whereas growth in social well-being was related to extraversion and conscientiousness. These findings may be explained by the relationship between personality and eudaimonic well-being (psychological and social well-being) in the behavioral mechanism. As Ozer and Benet-Martinez (2006) noted, personality traits are associated with behavioral functioning that includes positive relationships and personal virtues with regard to psychological well-being. For example, an individual with openness tends to accept new ideas and environments to change a habit or to engage in a new behavior, which may improve their daily quality of life (Lamers et al., 2012). Thus, the disposition of traits is related to behavioral functions and the influence of social well-being (Ozer & Benet-Martinez, 2006). Given the longitudinal estimates, our results showed that certain traits predict growth in social well-being, which indicates that some traits can shape social behavior and attitudes across time (Hill et al., 2012).

Our findings have several theoretical, methodological, and practical implications.

Theoretically, this study provides an understanding of the longitudinal association of the intensity of LTPA with psychological and social well-being. The different intensities of LTPA possess different features (e.g., levels of skill and challenge). In the context of eudaimonic well-being, the characteristics of activities are linked to an individual's pursuit of well-being (Zuo et al., 2017). In general, moderate LTPA requires simpler skills and challenges than vigorous LTPA. Given the decrease of physical ability over time, moderate LTPA could be associated with psychological and social well-being in the long term. Meanwhile, vigorous LTPA, requiring a high level of skill and challenge, may be related to more sustained well-being. That is, people with high psychological and social well-being would likely be attracted to vigorous LTPA over time, due to the characteristics of the activities that influence personal growth, purpose in life, and competence (Huta & Waterman, 2014). Thus, the intensity of LTPA is an important factor in any longitudinal association. Methodologically, the parallel LGCM provides some advantages for examination of the longitudinal association of LTPA and well-being. By comparison with cross-sectional studies using ANOVA or multiple regression, parallel LGCM enables the integration of between-individual and within-individuals changes, providing potential directional paths and suggesting an interrelationship between LTPA levels and types of well-being over several years (Curran et al., 2010). The parallel LGCM also allows us to explore both interindividual variability and intravariability in the growth trajectory of human behaviors (Duncan & Duncan, 2009). Therefore, the findings of this study using the parallel LGCM give us a better understanding of the longitudinal association between LTPA and well-being.

Practically, the findings indicate that policymakers should recognize the longitudinal relationship between LTPA and well-being. If policymakers seek to improve psychological and social well-being in the population, moderate LTPA would be an efficient resource for enhancing psychological and social well-being in the long term. The greater the psychological and social well-being achieved by moderate LTPA among the population, the higher the increase of vigorous LTPA over time. Accordingly, the findings can help practitioners better understand the longitudinal association in LTPA intensity and well-being to develop initiatives for community health and well-being.

Limitations and future directions

The limitations of this study should be acknowledged. First, the authors used a self-reported LTPA measure, which could be affected by bias in that respondents might overreport their LTPA levels. More detailed assessments could explicitly explain the impact of LTPA on well-being. Future studies could include time, frequency, duration, and types of participation at each LTPA level. Such detailed data would provide more specific information about individuals' engagement in different LTPA levels. Second, this study did not include a moderator or mediator between LTPA levels and types of well-being. Psychosocial need satisfaction might differ depending on the intensity of the LTPA. Thus, future research could examine the moderating or mediating effect of psychosocial need satisfaction in longitudinal association. Third, the authors did not include objective health status in this study. A change in health status could be closely associated with the association between LTPA and well-being. Future studies should also consider how objective health status changes across time moderate or mediate the longitudinal association of LTPA with well-being. Fourth, future studies could create a single model including LTPA intensities, psychological well-being, and social well-being, because psychological well-being and social well-being could be correlated. Finally, if future studies examine the association between changes in LTPA and well-being over a long time, the findings could provide a better understanding of the longitudinal relationship between LTPA intensities, psychological well-being, and social well-being.

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