Psychological needs satisfaction in physical education predicts a positive development of motivation in early adolescence: A latent growth modeling study

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Abstract

Self-determination theory is a compelling framework for understanding the psychological environment and explaining human motivation. This is especially crucial in school physical education (PE), given that the psychological environment within PE has been demonstrated to be closely related to the formation of physical activity motivation and behaviours. Advancing current knowledge and implementing a longitudinal approach, the aim of this study was, first, to investigate longitudinal changes in psychological needs and motivational regulation, and second, to examine the role of needs in the development of motivational regulation among PE students. A sample of 1,148 Finnish adolescents (583 girls, 565 boys, M_{age} = 11.27 ± .32) participated in annual assessments three times. A latent growth model analysis was used to examine the longitudinal associations between the outcome variables, namely psychological needs and motivational regulation. The results indicated that needs satisfaction (α_2 range -.20[.03] to -.06[.02]), intrinsic motivation (α_2 = -.38[.03]), and identified regulation (α_2 = -.19[.03]) declined, whereas external regulation (α_2 = .16[.02]) and amotivation (α_2 = .09[.02]) increased. Furthermore, the results demonstrated that psychological needs significantly predicted autonomous forms of motivational regulation (intrinsic motivation R^2 =.72[.13]; identified regulation R^2 =.69[.20]). Conversely, positive changes in autonomy (β = -.29[.13]) and relatedness (β = -.45[.22]) accounted for the negative changes in amotivation (R^2 =.62[.22]). In conclusion, the findings of the study corroborated the central postulations of the self-determination theory, providing empirical evidence of the importance of psychological needs in the development of motivation in PE.

Keywords: self-determination theory, motivational regulation, growth, structural equation modeling, early adolescence, physical education

Introduction

For individuals to effectively engage in productive, sustainable, and healthy behaviours, these behaviours must carry personal significance (Ryan et al., 2008). Research suggests that motivational experiences within educational settings (e.g. school physical education [PE]) can transfer into positive motivation beyond the PE context (e.g. leisure-time physical activity) (Hagger and Chatsizarantis, 2007; Yli-Piipari et al., 2018). Self-determination theory (SDT; Deci and Ryan, 1985, 2000), a prominent social-cognitive theory to explain human motivation, argues that psychological needs satisfaction is instrumental in the development of human motivation. However, it has been found that PE motivation declines during adolescence (Barkoukis et al., 2010; Ntoumanis et al., 2009; Säfvenbom et al., 2015). To gain a deeper understanding of the demonstrated decline in PE motivation during adolescence, a period when students undergo a plethora of biological, physiological, and social changes, we tracked the development of PE students' psychological needs and motivation across two school years. Grounded in SDT, this study aimed to investigate how adolescents' motivational regulation and perceived needs satisfaction develop within the context of school PE throughout the early school years.

Self-determination theory

SDT is a macro-theory of human motivation, growth, and well-being that distinguishes various qualities of an individual's motivation to predict their behaviour and psychological health (Deci and Ryan, 1985, 2000; Ryan and Deci, 2017). Considering innate psychological needs proposed as competence, autonomy, and relatedness allows us to explain different regulatory processes associated with the development of motivation and well-being (Deci and Ryan, 2000). Competence pertains to the need for success, ability, and confidence in demonstrating, achieving, and mastering desired goals and outcomes (Deci and Ryan, 2000). Autonomy refers to the need for self-regulation of experiences and actions (Deci and Ryan, 1985). Relatedness involves the need for connection and belonging to others (Deci and Ryan, 1985). Built on the premise that humans are inherently active and growth-oriented, SDT posits that optimal motivational development and well-being thrive when conditions facilitate the fulfillment of these innate needs (Deci and Ryan, 2000).

In the context of school PE, a need-supportive psychological environment is theorized to lead the positive development of PE motivation. Based on the SDT framework, humans exhibit different types of motivational regulation that range along a continuum from autonomous to controlled (Deci and Ryan, 1985, 2000; Ryan and Deci, 2017). Intrinsic motivation, the most autonomous form of motivation, is related to volitional behaviours driven by interest, which elicit spontaneous feelings of competence and enjoyment (Ryan and Deci, 2017). Extrinsic motivation, represented by instrumental behaviours, varies in terms of its degree of autonomy or control. Identified regulation, an autonomous form of extrinsic motivation, entails consciously assigning value to a behaviour as individual recognizes its importance (Deci and Ryan, 2000). Introjected regulation involves behaviours performed to seek others' approval or avoid internal pressures like feelings of guilt. Among the different types of extrinsic motivation, external regulation represents the most controlled form, referring to behaviours performed to attain rewards or avoid negative consequences. In contrast to intentional behaviours, amotivation is characterized by a complete lack of motivation for a target behaviour. Individuals experiencing amotivation do not have any goal or purpose for engaging in activities and often experience feelings of incompetence (Deci and Ryan, 1985). While intrinsic motivation and internalized forms of extrinsic motivation (i.e. integrated regulation and identified regulation) are autonomous and adaptive, controlling forms of motivation (i.e. introjected regulation and external regulation) and amotivation result in a controlling (non-autonomous) motivational profile and maladaptive behaviours that hinder one's goals or well-being in a particular context (Ryan and Deci, 2000).

Needs satisfaction and motivational regulation in PE

Consistent with SDT (Deci and Ryan, 1985), previous research has demonstrated the vital role of psychological needs satisfaction in predicting motivational regulation in PE (White et al., 2021). It has been shown that PE teachers' need-support and students' autonomous PE motivation are mediated by students' needs satisfaction (Rutten et al., 2012). Analysing 265 relevant studies, Vasconcellos et al. (2020) have shown a strong and positive relationship between the satisfaction of basic psychological needs and students' autonomous motivation in PE, alongside a weak negative association with external regulation. Specifically, satisfaction of autonomy, competence, and relatedness exhibited strong correlations with intrinsic motivation and identified regulation, and a moderately positive correlation with introjected regulation. Amotivation, on the other hand, displayed a moderate negative correlation with needs satisfaction (Vasconcellos et al., 2020).

To build upon the correlational evidence, longitudinal research has been utilized to examine the patterns of change in adolescents' psychological needs and motivational regulation in PE. This line of research has shown that adolescents' physical activity needs satisfaction tends to decrease over time (Gunnell et al., 2015). Partially corroborating the Gunnell et al. (2015) study, a study focusing on early adolescence reported an increase in students' competence but a decrease in autonomy and relatedness within school PE (McDavid et al., 2014). Regarding the changes in motivational regulation in PE, longitudinal research has shown a decline in autonomous forms of motivation (i.e. intrinsic motivation and identified regulation), whereas the development of extrinsic motivation (i.e. introjected and external regulation) has been observed to increase or remain stable as individuals grow older (Ntoumanis et al., 2009; Ullrich-French and Cox, 2014; Yli-Piipari et al., 2012). However, contradictory research suggests that motivation can become more autonomous across adolescence (Dishman et al., 2015). By using multilevel latent growth modeling, Jaakkola et al. (2015) indicated that Finnish adolescents' identified regulation and amotivation increased while their introjected regulation declined. Notably, these changes in introjected regulation and amotivation were influenced by individual factors, whereas the changes in identified regulation were due to environmental factors such as teachers, friends, and/or family.

Present study

Previous studies have highlighted the positive contribution of autonomy, competence, and relatedness to the development of self-determined PE motivation, and this evidence has been primarily derived from cross-sectional correlational and regression studies (Cox et al., 2008; Fin et al., 2019; McDavid et al., 2014; Rutten et al., 2015). Previous studies illustrating the longitudinal changes in psychological needs and motivational regulation have been scarce in numbers and contradictory in results (Dishman et al., 2015; Jaakkola et al., 2015; Ntoumanis et al., 2009; Ullrich-French and Cox, 2014; Yli-Piipari et al., 2012). Thus, there is a need for longitudinal studies to understand the role of each psychological need in the motivational process. The first aim of this study was to investigate the development of psychological needs and motivational regulation among adolescents in the context of PE. We hypothesized that needs satisfaction and autonomous motivation in PE would decline while controlling motivation would increase over time. To recognize the previous research findings that have shown gender differences in the development of PE motivation and needs satisfaction (Cairney et al., 2012; Yli-Piipari et al., 2012), gender and body mass index (BMI) were controlled in the analyses. While no previous study directly establishes a link between BMI and the development of motivation or psychological needs in PE, higher BMI has been found to exhibit a negative relationship with physical activity in PE (Gao et al., 2011; Grao-Cruces et al., 2020). The secondary aim of the study was to examine the predictive role of psychological needs in the development of motivational regulation. Although the correlation between psychological needs and self-determined motivation has been well established (Cox et al., 2018; Fin et al., 2019; Vasconcellos et al., 2020), more longitudinal research evidence is needed to establish a strong hypothesis. Based on the theorization of SDT, we expected that psychological needs would be instrumental in the development of human motivation, with greater needs satisfaction being associated with more autonomous forms of motivation (Deci and Ryan, 2000).

Method

Participants and procedure

A nationally representative sample of 1,148 Finnish students in early adolescence (583 girls, 565 boys) from 35 schools was collected. Participants were 10- to 12-year-olds ($M = 11.27$, $SD = .32$) at the beginning of the study (T0). The study was approved by the institutional review board at the University of Jyväskylä and conformed to standards for the use of human participants in research as outlined in the Declaration of Helsinki. Each participant and their guardians were informed of the purpose of the study, procedures, and potential risks before providing their written consent and assent to participate. Participants were assessed three times every fall from 5th to 7th grades (T0, $n = 1{,}148$; T1, $n = 1{,}022$; T2, $n = 888$). All measurements were carried out by PE teachers and supervised by researchers during a pre-determined school PE lesson.

Measures

PE motivation: Participants' motivation towards PE was analysed by the Finnish version of the Perceived Locus of Causality Scale (PLOC-R; Vlachopoulos et al., 2011a). The PLOC-R includes the item stem: "I take part in PE…" and all items were rated on a five-point Likert scale ranging from *1 = strongly disagree* to *5 = strongly agree*. The scale includes 19 items measuring participants' intrinsic motivation (four items; e.g. "Because PE is exciting"), identified regulation (four items; e.g. "Because it is important to me to do well in PE"), introjected regulation (four items; e.g. "Because I want others to think I'm good"), external regulation (three items; e.g. "Because that's what I'm supposed to do"), and amotivation (four items; e.g. "But I really don't know why"). This study did not measure integrated regulation, as it has been found to be unidentifiable among children and young adolescents (Baldwin and Caldwell, 2003; Stover et al., 2012). Previously, this scale has been shown to be a valid and reliable tool for analysing PE motivation in Finnish children and adolescents (Huhtiniemi et al., 2019). The Cronbach's alphas for this sample across the variables were acceptable, ranging from 0.65 to 0.84.

Needs satisfaction in PE: The Basic Psychological Needs in Physical Education Scale (BPN-PE; Vlachopoulos et al., 2011b) was used to measure psychological needs satisfaction in PE. All items are preceded by the stem "In general in PE..." and they are rated on a five-point Likert scale ranging from *1 = strongly disagree* to *5 = strongly agree*. The Finnish version of the BPN-PE consists of 12 items, comprising the satisfaction of autonomy (four items; e.g. "the activities we are doing have been chosen by me"), competence (four items; e.g. "I perform correctly even the tasks considered difficult by most of the children"), and relatedness (four items; e.g. "My relationship with my classmates are very friendly"). Vlachopoulos et al. (2011b) demonstrated strong internal reliability and validity of this scale for all three school grade levels. Validity in the Finnish population has been reported as well (Huhtiniemi et al., 2019). The Cronbach's alphas for this sample across the variables were good, with values ranging from .77

to .90.

Controlling variables: Sex (dichotomous; male/female based on biological sex) and BMIz were controlling variables in this study. The researchers measured the participants' height and weight using a digital scale and a portable stadiometer to the nearest .1cm and .01kg, respectively. Participants were measured without shoes and in light clothing. BMI was calculated as weight (kg) divided by height (m) squared (BMI = weight/height^2). Standardized BMI (BMIz) was calculated according to the classification standards set by the World Health Organization (Onis et al., 2007; World Health Organization, 2007) using the SPSS macro provided by the World Health Organization (2007). This method is considered valid and reliable (Onis et al., 2007; World Health Organization, 2007).

Statistical analysis

Descriptive statistics of the students' psychological needs and motivational regulation across time were tabulated. A robust Maximum Likelihood (MLR) estimator was used to provide robust parameter estimates, addressing the potential non-normality of the response scales. In addition, missing responses were accounted for using the Full Information Maximum Likelihood (FIML; Enders, 2010) procedures. To estimate the growth of the primary outcome variables, latent growth models were conducted separately for each outcome variable (Duncan et al., 1999). Using a latent growth curve model, adolescents' initial level (Intercept, α_1), growth trajectory (Slope, α_2) of the research variables, and the strength of associations between the intercept and slope components were examined. The linear models were constructed by fixing the loadings of the observed variables to 1 on the intercept and to 0, 1, and 2 on the slope, across T0 to T2. The residual variances of the observed variables were allowed to be estimated. The linear and non-linear models were estimated following the recommendation of Curran et al. (2010). First, the random intercept-only model was estimated, following the linear and non-linear models. Since the data had only three measurement points, the potential quadratic model was estimated by letting one measurement point be freely estimated. For the conditional models, sex (time-invariant) and BMIz (time-variant) variables were incorporated into all models as covariates. Finally, regression path models were set up to estimate the role of psychological needs in the development of motivational regulation by placing all conditional models in the following path model (Figure 1). Statistically significant latent motivational regulation intercepts and slopes were estimated by latent intercepts and slopes from psychological needs. In addition, latent intercepts and slopes were allowed to correlate.

All the analyses were performed within a structural equation modeling framework using the Mplus statistical package (Version 8.10; Muthén and Muthén, 1998–2021). Multi-level models were employed to estimate between-school differences in variables. A Huber-White sandwich estimator, robust to heteroscedasticity and group-correlated responses, was used to adjust the nesting effects with the participants within schools by correcting the standard errors of parameter estimates for between-school variance (Asparouhov, 2005).

Model fit was tested using the following parameters: Chi-squared test, Bentler comparative fit index (*CFI*), Tucker-Lewis index (*TLI*), and Root Mean Squared Error of Approximation (*RMSEA*) (Hu and Bentler, 1999). It is known that the chi-squared test is almost always significant when samples approximate or exceed 400 cases (Lin et al., 2013). Thus, other fit indices were employed as recommended in previous studies (Hu and Bentler, 1999). CFI values of ≥ .90 and .95 were used to indicate acceptable and good fit. RMSEA value of ≤ .06 was used to represent close fit (Hu and Bentler, 1999). The sample size was adequate for all model tests. Statistical power exceeded .90 at an alpha of .05 for rejecting good fit at an RMSEA of .06

and a conservative estimate of model complexity at 10 df (MacCallum et al., 1996; MacCallum et al., 2006). To test competing nested models, a two-group chi-squared difference test was conducted (Bollen, 1989).

INSERT Figure 1.

Results

Descriptive statistics

Our analysis suggested small and non-significant variance between schools (intra-class correlation coefficient; ICC) in competence (T0: .001; T1: .001; T2: .001) and relatedness (T0: .009; T1: .010; T2: .014). Between-school variance was also small and statistically non-significant in motivational regulation (ICC from T0 to T2 $\leq$ .011). Table 1 presents the ranges, means, and standard deviations of the psychological needs, motivational regulation, and BMIz at the three measurement points. No statistically significant sex difference was observed in BMIz scores from Time 0 to Time 2. The statistically significant sex differences in the outcome variables are illustrated in Table 1.

INSERT Table 1.

Unconditional latent growth model

Separate unconditional latent growth curve models were estimated for each variable across the three time points. Details regarding the overall model fit information and difference testing results can be found in Appendix 1 of the supplemental material, while Table 2 presents the optimal and final estimates of the intercept and the slope components. Except for introjected regulation, models fit adequately or well with linear slopes according to the descriptive fit indices. However, the model fit for autonomy was not acceptable, thus it was not interpreted. For introjected regulation, a non-linear, quadratic growth pattern (saturated model with freely estimated factor loading from slope on T2 values (Curran et al., 2010)) represented the change better (CFI = 1.00, TLI = 1.00). The analysed data showed that participants had moderately high needs satisfaction (competence α_1 = 3.43[.03]; relatedness α_1 = 3.73[.04]). In addition, participants reported high levels of autonomous motivation (intrinsic α_1 = 4.18[.04]; identified α_1 = 3.64[.03]) and low levels of controlling motivation (external α_1 = 1.93[.03]; amotivation α_1 = 1.49[.02]).

Participants' needs satisfaction declined across time, with the negative slope (α_2) value demonstrating the rate of change per each time point (competence α_2 = -.06[.02]; relatedness α_2 = -.09[.02]). Similarly, autonomous forms of motivational regulation declined (intrinsic α_2 = -.38[.03]; identified α_2 = -.19[.03]), whereas controlling forms of motivational regulation increased (external α_2 = .16[.02]; amotivation α_2 = .09[.02]). Introjected regulation was shown to increase between T0 and T1, with the slope (α_2 = .64) representing a positive and relatively large change (ψ_{22} = .23[10]) from T0 to T1. In addition, the estimated factor loading of slope on T2 (.66) suggests that introjected regulation declined dramatically from T1 to T2 (to interpret T2 value, the value should be compared to the value 1; with the values < 1 suggesting a declining pattern, whereas the values > 1 are suggesting an increasing trajectory). Finally, it is noteworthy that individual differences in all study variables declined across time with covariance of latent components (ψ_{21}) ranging from -.08 to -.02.

INSERT Table 2.

Conditional latent growth models

To control the roles of sex (0 = male, 1 = female) and BMIz on the development of needs and motivation, separate conditional models were estimated. When adding the covariates, overall model fit improved resulting in a good model fit for each conditional model. Table 3 reports the estimates of the covariates, which illustrate the role of sex and BMIz, together with the slope and intercept estimates. The quadratic time trend was included for introjected regulation, but covariate effects were not interpreted as it was a saturated model. Similar to other psychological needs, autonomy exhibited a relatively high baseline score (α_1 = 3.19[.03]) and declined over time (α_2 = -.20[.03]). Sex played a statistically significant role in competence (β_i = -.12[.04]), with boys reporting higher levels of competence satisfaction. Additionally, boys exhibited higher identified regulation (β_i = -.17[.04]) compared to girls. However, these relationships were only evident at the intercept level, suggesting that these differences were apparent only at the baseline. BMIz, as a time-variant covariate, showed a negative relationship with needs satisfaction and autonomous forms of motivation. Specifically, BMIz was a statistically significant factor influencing psychological needs (β_{range} = -.13[.03] to -.02[.04]), but it had a relatively weaker association with motivational regulation. In terms of motivational regulation, there were associations found between BMIz and intrinsic motivation (T1), as well as between BMIz and amotivation (T1 & T2). Higher BMIz was related to lower intrinsic motivation (β_i = -.07[.03]) and higher amotivation (β_{range} = .08[.03] to .11[.02]). The relationships between BMIz and needs satisfaction, as well as motivational regulation, were stronger in T1 and T2 compared to T0.

INSERT Table 3.

Regressive models

Regressive model analyses were conducted to test the predictive strength of the three psychological needs on motivational regulation (Figure 1), and the results are presented in Table 4. The model did not converge due to exceeding the maximum number of iterations. To improve parsimony, we removed the correlation between latent variables, leaving only regressive relationships in the model. The revised model was found to be identifiable and marginally acceptable: $\chi^2(251) = 2876.27$, p <.001, CFI = .92, TLI = .90, RMSEA = .068, 90% CI [.05, .08].

Regressive model analyses showed that the positive development (Slopes [α_2]) of autonomy, competence, and relatedness predicted the positive development of intrinsic motivation (βs ranging between .35[.15] and 66[.12]). These predictors, along with the intercepts of psychological needs, accounted for 72% of the positive changes in intrinsic motivation (R^2 = .72[.19]). In addition, positive changes in autonomy (β = .47[.09]) and competence (β =.75[.09]) explained a large portion of positive changes in identified regulation (R^2 = .69[.20]). Finally, positive changes in autonomy (β = -.29[.13]) and relatedness (β = -.45[.22]) explained the negative changes in amotivation (R^2 = .62[.22]). In terms of the relationship from α_1 to α_2, the intercept of the needs was not a statistically significant predictor of the slope in any motivational regulation.

INSERT Table 4.

Discussion and conclusion

This study was conducted to examine the development of psychological needs satisfaction and motivational regulation in PE among early adolescents. Furthermore, the study aimed to investigate the predictive role of psychological needs in the development of motivation. The study's primary finding was that participants' needs satisfaction and the autonomous forms of motivational regulation declined across early adolescence, while controlling motivation increased. In addition, the study showed that psychological needs had a long-term positive association with intrinsic motivation and identified regulation, and needs satisfaction was a protector against amotivation in school PE.

Descriptive results of the study showed that Finnish adolescents exhibit high levels of adaptive motivation and moderately high levels of needs satisfaction in PE. These results align with a prior cross-sectional study involving Finnish fifth and ninth-grade students, which indicated high scores in psychological needs and autonomous forms of motivation in PE (Huhtiniemi et al., 2019). These trends are consistent in various countries. Ommundesen and Kvalo (2007) discovered relatively high levels of intrinsic motivation, autonomy, and competence perception among 194 10th-grade students in Norway, while Rutten et al. (2015) observed similar findings in Belgium, where 472 early adolescents demonstrated elevated levels of autonomous motivation and perception of competence towards PE. Likewise, 1,221 Chinese students aged 11 to 16 reported higher intrinsic and identified motivation as well as higher needs satisfaction in PE than the midpoint of the scale (Chen et al., 2020). Furthermore, in our study, boys demonstrated higher levels of self-determined motivation (intrinsic motivation and identified regulation) and perceived competence compared to girls. These findings are consistent with the observation that Finnish fifth-grade boys exhibited higher autonomous forms of motivation compared to girls (Yli-Piipari et al., 2021). Also, the findings of this study added evidence to existing literature suggesting that boys tend to perceive higher competence in PE than girls (Guan et al., 2023; Rutten et al., 2012). At the same time, in our study, boys displayed higher levels of amotivation in PE than girls, which has not been prominently highlighted in previous research. This is an interesting finding, as high competence typically relates to low levels of amotivation (Vasconcellos et al., 2020). One reason could be that some tasks in PE may not be challenging enough for boys. If that is the case, it may contribute to boys' high perceptions of competence, but simultaneously to a lack of motivation.

Our analyses revealed a declining trend across time in participants' psychological needs satisfaction and autonomous forms of motivational regulation, accompanied by an increase in controlling motivation. The change for each variable was linear, except for introjected regulation, which showed a steep increase between T0 and T1, followed by a decline between T1 and T2. Our findings support the previous research, which has reported a decline in adolescents' needs satisfaction and autonomous motivation in PE and physical activity contexts (Gunnell et al., 2015; Ntoumanis et al., 2009; Ullrich-French and Cox, 2014). Reasons for the decline of psychological needs and autonomous forms of motivational regulation are largely unknown. This may attribute to adverse changes in school PE environment, which thwart students' psychological needs in PE. Alternatively, these changes could be linked to the psychological and social development of young adolescents (Gardner et al., 2012). Early adolescence is a critical time for the development of executive function, which encompasses the ability to make independent decisions, execute them effectively, accomplish goals, and cultivate healthy social networks (Gardner et al., 2012). Hence, it may be that this age group is uniquely sensitive to the psychological environment in school PE. In addition, our analyses suggested that boys' and girls' development of psychological needs and motivational regulation were similar, but students with higher BMIz experienced a greater decline in needs satisfaction compared to students with lower BMIz. Similarly, BMIz had a weak negative relationship with intrinsic motivation and a weak positive relationship with amotivation. Empirical evidence from numerous studies has indicated that needs satisfaction and autonomous motivation in PE contribute to positive changes in adolescents' healthy lifestyles, such as increased leisure-time physical activity (Hutmacher et al., 2020; McDavid et al., 2014; Yli-Piipari et al., 2018). Therefore, the findings of the current study are concerning and could partially explain the reported decline in physical activity levels among Finnish adolescents (Husu et al., 2023).

To examine the role of psychological needs in the development of motivational regulation, the regressive model was conducted. Our analyses revealed that change over time in three psychological needs predicted the development of intrinsic motivation, accounting for 72% of the positive changes observed. In addition, positive changes in autonomy and competence explained a substantial proportion of the changes observed in identified regulation ($R^2 = .69$). The changes in autonomy and relatedness explained 60% of the variation in amotivation, suggesting that the declining trends in these psychological needs contributed to an increase in amotivation towards PE. These findings are largely consistent with the results of a review study conducted by Vasconcellos et al. (2020), which concluded that the satisfaction of three psychological needs is strongly correlated with autonomous motivation. However, like most previous research, this review study's findings were largely derived from cross-sectional correlation studies. To the best of the authors' knowledge, no previous longitudinal study has explored the predictive role of psychological needs in the development of motivational regulation by comparing trajectories of needs satisfaction and motivation. In this sense, our research findings add further evidence to the predictive role of psychological needs in shaping students' motivation in PE from a new perspective.

This study is not free from limitations. While this study benefits from adopting a longitudinal approach, which provides a stronger foundation compared to primarily cross-sectional findings explaining the correlation between psychological needs and motivational regulation, it is essential to acknowledge that similarities in growth trajectories do not establish direct evidence of a causal relationship between psychological needs and motivation. Also, in this study, we did not measure integrated regulation. This is because previous studies have shown that integrated regulation may not be easily identifiable in young populations as it takes time and maturity for individuals to develop a greater understanding and awareness of behaviours that are personally valuable to them (Baldwin and Caldwell, 2003; Stover et al., 2012). Lastly, the model fit of some of the models could have been better. Future studies should explore whether model fit can be improved by adding meaningful covariates or more measurement points to control the covariance of the growth trajectories.

In conclusion, this study demonstrated a negative development of psychological needs satisfaction and motivation across early adolescence, whereas controlling motivation increased in PE. In addition, the study showed that psychological needs had a long-term positive relationship with intrinsic motivation and identified regulation, and needs satisfaction served as a protector against amotivation towards school PE. These findings support the central tenet of SDT, suggesting that satisfaction of psychological needs is instrumental in developing autonomous motivation in PE. Further studies are needed to examine the role of PE teachers in developing students’ psychological needs and motivation. In addition, longer-term panel studies tracking the development of motivation and physical activity would provide more insightful data on the impact of PE motivation on the actual amount of physical activity.

This study offers practical educational implications for PE teachers. Longitudinal findings indicate that supporting students' needs would positively influence the development of autonomous motivation while reducing controlling motivation in PE. Haerens et al. (2015) study emphasized that students' perception of autonomy in teaching leads to autonomous motivation through needs satisfaction in PE. This underscores the importance of PE teachers being attentive to students' needs and proactively addressing them to counteract the declining trends in needs satisfaction and self-determined motivation during early adolescence. In general, supporting students' needs for autonomy, competence, and relatedness is conceptualized as providing autonomous choices, clear structure, and caring interpersonal relationships, respectively (Stroet et al., 2013). Considering the predictive power of the three psychological needs in fostering intrinsic motivation, as demonstrated by this study, it is paramount for PE teachers to support autonomy, competence, and relatedness simultaneously to facilitate the optimal development of students' motivation.

References

Asparouhov T (2005) Sampling weights in latent variable modeling. *Structural Equation Modeling* 12(3): 411-434.

Baldwin CK, Caldwell LL (2003) Development of the free time motivation scale for adolescents. *Journal of Leisure Research* 35(2): 129-151.

Barkoukis V, Ntoumanis N, Thøgersen-Ntoumani C (2010) Developmental changes in achievement motivation and affect in physical education: Growth trajectories and demographic differences. *Psychology of Sport and Exercise* 11(2): 83-90.

Bollen KA (1989) *Structural Equations with Latent Variables* (Vol. 210). New York, NY: John Wiley & Sons.

Cairney J, Kwan MY, Velduizen S, et al. (2012) Gender, perceived competence and the enjoyment of physical education in children: A longitudinal examination. *International Journal of Behavioral Nutrition and Physical Activity* 9: 1-8.

Chen R, Wang L, Wang B, et al. (2020) Motivational climate, need satisfaction, self-determined motivation, and physical activity of students in secondary school physical education in China. *BMC Public Health* 20: 1-14.

Cheong J, MacKinnon DP, Khoo ST (2021) Investigation of mediational processes using parallel process latent growth curve modeling. *Structural Equation Modeling* 10(2): 238-262.

Cox A, Williams L (2008) The roles of perceived teacher support, motivational climate, and psychological need satisfaction in students' physical education motivation. *Journal of Sport and Exercise Psychology* 30(2): 222-239.

Curran PJ, Obeidat K, Losardo D (2010) Twelve frequently asked questions about growth curve modeling. *Journal of Cognitive Development* 11(2): 121-136.

Deci EL, Ryan RM (1985) *Intrinsic Motivation & Self-Determination in Human Behavior*. New York, NY: Plenum Press.

Deci EL, Ryan RM (2000) The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry* 11(4): 227-268.

Deci EL, Ryan RM (2008) Self-determination theory: A macrotheory of human motivation, development, and health. *Canadian Psychology/Psychologie Canadienne* 49(3): 182-185.

Dishman RK, McIver KL, Dowda M, et al. (2015) Motivation and behavioral regulation of physical activity in middle-school students. *Medicine and Science in Sports and Exercise* 47(9): 1913-1921.

Duncan TE, Duncan SC, Strycker LA, et al. (1999) *An Introduction to Latent Variable Growth Curve Modeling: Concepts, Issues, and Applications*. Mahwah, NJ: Lawrence Erlbaum Associates.

Enders CK (2010) *Applied Missing Data Analysis.* New York, NY: Guilford Press.

Fin G, Moreno-Murcia JA, León J, et al. (2019) Teachers' interpersonal style in physical education: Exploring patterns of students' self-determined motivation and enjoyment of physical activity in a longitudinal study. *Frontiers in Psychology* 9: 2721.

Fredricks JA, Eccles JS (2002) Children's competence and value beliefs from childhood through adolescence: Growth trajectories in two male-sex-typed domains. *Developmental Psychology* 38(4): 519-533.

Gao Z, Oh H, Sheng H (2011) Middle school students' body mass index and physical activity levels in physical education. *Research Quarterly for Exercise and Sport* 82(1): 145-150.

Gardner B, Lally P, Wardle J (2012) Making health habitual: The psychology of 'habit-formation' and general practice. *British Journal of General Practice* 62(605): 664-666.

Grao-Cruces A, Racero-García A, Sánchez-Oliva D, et al. (2020) Associations between weight status and situational motivation toward fitness testing in physical education: The mediator role of physical fitness. *International Journal of Environmental Research and Public Health* 17(13): 4821.

Guan J, Xiang P, Land WM, et al. (2023) The roles of perceived physical education competence, enjoyment, and persistence on middle school students’ physical activity engagement. *Perceptual and Motor Skills* 130(4): 1781-1796.

Gunnell KE, Bélanger M, Brunet J (2016) A tale of two models: Changes in psychological need satisfaction and physical activity over 3 years. *Health Psychology* 35(2): 167-177.

Haerens L, Aelterman N, Vansteenkiste M, et al. (2015) Do perceived autonomy-supporti ve and controlling teaching relate to physical education students' motivational expe riences through unique pathways? Distinguishing between the bright and dark side of motivation. *Psychology of Sport and Exercise* 16: 26-36.

Hagger M, Chatzisarantis N (2007) *Self-Determination Theory in Exercise and Sport*. Champaign, IL: Human Kinetics.

Hu LT, Bentler PM (1999) Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal* 6(1): 1-55.

Huhtiniemi M, Sääkslahti A, Watt A, et al. (2019) Associations among basic psychological needs, motivation, and enjoyment within Finnish physical education students. *Journal of Sports Science & Medicine* 18(2): 239-247.

Husu P, Tokola K, Vähä-Ypyä H, et al. (2023) Liikemittarilla mitatun liikkumisen, paikallaanolon ja unen määrä. In: Kokko S and Martin L (eds) *The Physical Activity Behaviours of Children and Adolescents in Finland. Results of the LIITU study 2022.* Publications of the national sport council, pp.31-47.

Hutmacher D, Eckelt M, Bund A, et al. (2020) Does motivation in physical education have an impact on out-of-school physical activity over time? A longitudinal approach. *International Journal of Environmental Research and Public Health 17*(19): 7258.

Jaakkola T, Wang J, Yli-Piipari S, et al. (2015) A multilevel latent growth modelling of the longitudinal changes in motivation regulations in physical education. *Journal of Sports Science & Medicine* 14(1): 164-171.

Lin M, Lucas Jr HC, Shmueli G (2013) Research commentary—too big to fail: Large samples and the p-value problem. *Information Systems Research* 24(4): 906-917.

Ntoumanis N, Barkoukis V, Thøgersen-Ntoumani C (2009) Developmental trajectories of motivation in physical education: Course, demographic differences, and antecedents. *Journal of Educational Psychology* 101(3): 717-728.

MacCallum RC, Browne MW, Cai L (2006) Testing differences between nested covariance structure models: Power analysis and null hypotheses. *Psychological Methods* 11(1): 19-35.

MacCallum RC, Browne MW, Sugawara HM (1996) Power analysis and determination of sample size for covariance structure modeling. *Psychological Methods* 1(2): 130-149.

McDavid L, Cox AE, McDonough MH (2014) Need fulfillment and motivation in physical education predict trajectories of change in leisure-time physical activity in early adolescence. *Psychology of Sport and Exercise* 15(5): 471-480.

Murcia JAM, Gimeno EC, Coll DGC (2008) Relationships among goal orientations, motivational climate and flow in adolescent athletes: Differences by gender. *The Spanish Journal of Psychology* 11(1): 181-191.

Muthén LK, Muthén B (1998-2021). *Mplus User's Guide.* Los Angeles, CA: Muthén & Muthén.

Onis MD, Onyango AW, Borghi E, et al. (2007) Development of a WHO growth reference for school-aged children and adolescents. *Bulletin of the World Health Organization* 85(9): 660-667.

Ommundsen Y, Kvalø SE (2007) Autonomy–mastery, supportive or performance focused? Different teacher behaviours and pupils' outcomes in physical education. *Scandinavian Journal of Educational Research* 51(4): 385-413.

Rutten C, Boen F, Seghers J (2012) How school social and physical environments relate to autonomous motivation in physical education: The mediating role of need satisfaction. *Journal of Teaching in Physical Education* 31(3): 216-230.

Rutten C, Boen F, Vissers N, et al. (2015) Changes in children's autonomous motivation toward physical education during transition from elementary to secondary school: A self-determination perspective. *Journal of Teaching in Physical Education* 34(3): 442-460.

Ryan RM (1995) Psychological needs and the facilitation of integrative processes. *Journal of Personality* 63(3): 397-427.

Ryan RM, Deci EL (2000) Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist* 55(1): 68-78.

Ryan RM, Deci EL (2017) *Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness.* New York: Guilford Publications.

Ryan RM, Patrick H, Deci EL, et al. (2008) Facilitating health behaviour change and its maintenance: Interventions based on self-determination theory. *European Health Psychologist* 10(1): 2-5.

Säfvenbom R, Haugen T, Bulie M (2015) Attitudes toward and motivation for PE. Who collects the benefits of the subject? *Physical Education and Sport Pedagogy* 20(6): 629-646.

Stover JB, De La Iglesia G, Boubeta AR, et al. (2012) Academic motivation scale: Adaptation and psychometric analyses for high school and college students. *Psychology Research and Behavior Management* 5: 71-83.

Stroet K, Opdenakker MC, Minnaert A (2013) Effects of need supportive teaching on early adolescents' motivation and engagement: A review of the literature. *Educational Research Review* 9: 65-87.

Ullrich-French S, Cox AE (2014) Normative and intraindividual changes in physical education motivation across the transition to middle school: A multilevel growth analysis. *Sport, Exercise, and Performance Psychology* 3(2): 132-147.

Vasconcellos D, Parker PD, Hilland T, et al. (2020) Self-determination theory applied to physical education: A systematic review and meta-analysis. *Journal of Educational Psychology* 112(7): 1444-1469.

Vlachopoulos SP, Katartzi ES, Kontou MG, et al. (2011a) The revised perceived locus of causality in physical education scale: Psychometric evaluation among youth. *Psychology of Sport and Exercise* 12(6): 583-592.

Vlachopoulos SP, Katartzi ES, Kontou MG (2011b) The basic psychological needs in physical education scale. *Journal of Teaching in Physical Education* 30(3): 263-280.

White RL, Bennie A, Vasconcellos D, et al. (2021) Self-determination theory in physical education: A systematic review of qualitative studies. *Teaching and Teacher Education* 99: 103247.

World Health Organization (2007) *Growth Reference Data for 5-19 years*. Available at: https://www.who.int/tools/growth-reference-data-for-5to19-years/application-tools

Yli-Piipari S, Gråsten A, Huhtiniemi M, et al. (2021) Predictive strength of physical educationcentered physical literacy indicators on physical activity. *Journal of Teaching in Physical Education* 40(2): 303-311.

Yli-Piipari S, Layne T, Hinson J, et al. (2018) Motivational pathways to leisure-time physical activity participation in urban physical education: A cluster-randomized trial. *Journal of Teaching in Physical Education* 37(2): 123-132.

Yli-Piipari S, John Wang CK, Jaakkola T, et al. (2012) Examining the growth trajectories of physical education students' motivation, enjoyment, and physical activity: A person-oriented approach. *Journal of Applied Sport Psychology* 24(4): 401-417.

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Appendix 1

Results of the unconditional latent growth models for the psychological needs and motivational regulations

Model	$\chi^2(df)$	CFI	TLI	RMSEA	$\Delta\chi^2(df)$	Δp-value	ΔCFI	ΔTLI	ΔRMSEA
Autonomy									
Intercept Only	32.71(4)	.86	.83	.245	-	-	-	-	-
Linear	30.96(1)	.88	.85	.209	1.75(3)	.001	+.02	+.01	-.036
Quadric	Saturated model		-	-	-	-	-	-	-
Competence									
Intercept Only	.15(4)	.98	.98	< .001	-	-	-	-	-
Linear	.01(1)	1.00	1.00	< .001	.13(3)	< .001	+.02	+.02	< .001
Quadric	Saturated model		-	-	-	-	-	-	-
Relatedness									
Intercept Only	.78(3)	.98	.97	.002	-	-	-	-	-
Linear	.57(1)	1.00	1.00	< .001	.16(3)	.001	+.02	-.02	-.024
Quadric	Saturated model								
Intrinsic									
Intercept Only	16.21(4)	.90	.86	.172	-	-	-	-	-
Linear	29.46(1)	.93	.88	.157	13.75(3)	-.015	+.03	+.02	-.015
Quadric	Saturated model		-	-	-	-	-	-	-
Identified									
Intercept Only	.56(4)	.97	.98	.196	-	-	-	-	-
Linear	.23(1)	1.00	1.00	< .001	.33(3)	.239	+.03	+.02	-.234
Quadric	Saturated model		-	-	-	-	-	-	-
Introjected									
Intercept Only	73.41(4)	.65	.75	.267	-	-	-	-	-
Linear	72.47(1)	.66	.75	.250	.94	.362	+.02	.00	-.16
Quadric	Saturated model		-	-	-	-	-	-	-
External									
Intercept Only	10.89(4)	.96	.92	.110	-	-	-	-	-
Linear	9.64(1)	.98	.93	.087	1.25	< .001	+.02	+.01	-.23
Quadric	Saturated model		-	-	-	-	-	-	-
Amotivation									
Intercept Only	3.12(4)	.98	.97	.114	-	-	-	-	-
Linear	2.11(1)	.99	.98	.031	1.01	< .001	+.02	+.01	-.008
Quadric	Saturated model		-	-	-	-	-	-	-

Note: The unstandardized solutions.

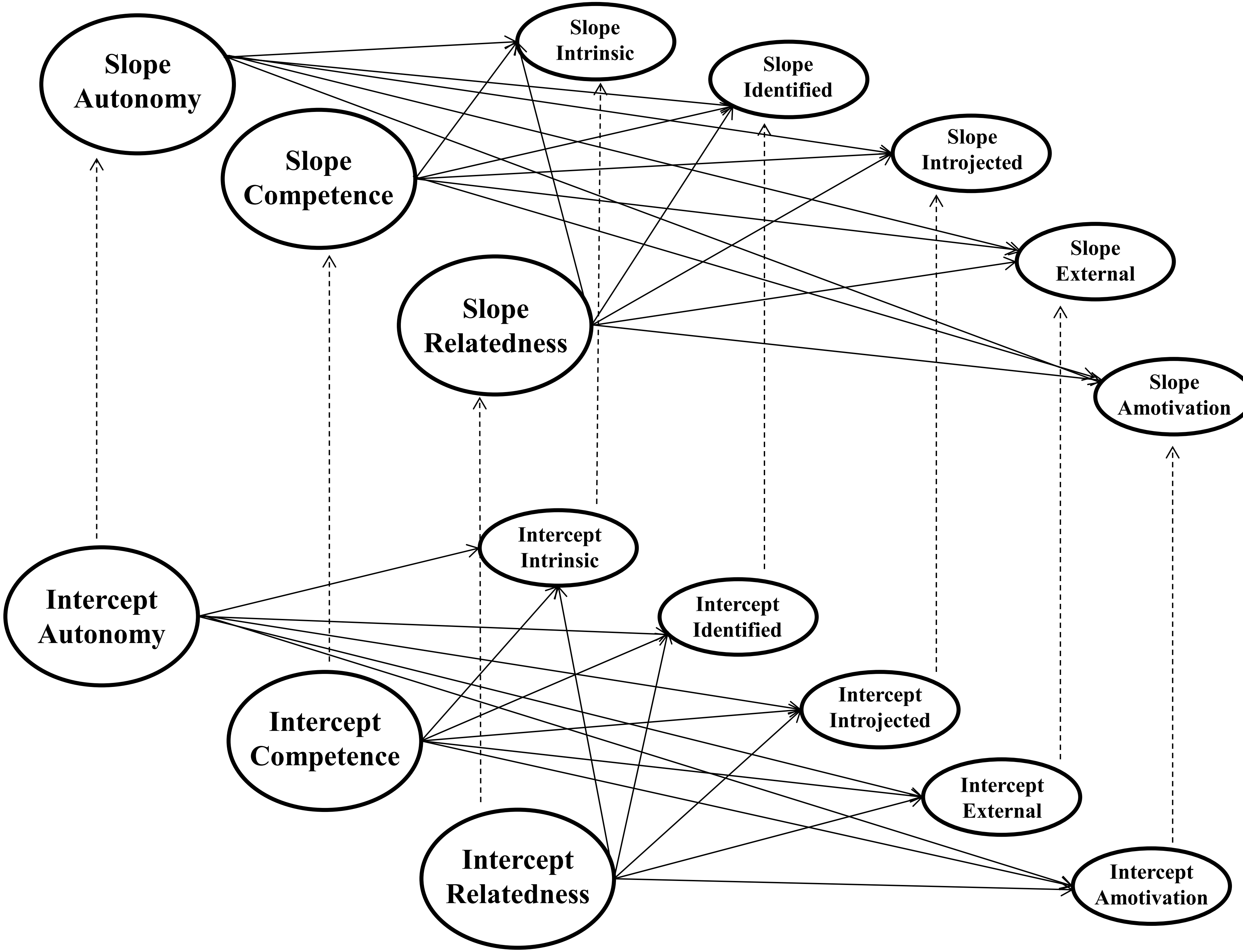
Slope Autonomy
Slope Competence
Slope Relatedness
Slope Intrinsic
Slope Identified
Slope Introjected
Slope External
Slope Amotivation
Intercept Autonomy
Intercept Competence
Intercept Relatedness
Intercept Intrinsic
Intercept Identified
Intercept Introjected
Intercept External
Intercept Amotivation

Table 1. Descriptive statistics of the study variables

	Total Sample					Female			Male		
	N	Range	M(SD)	Skew(SE)	Kur(SE)	N	Range	M(SD)	N	Range	M(SD)
BMI T0	1121	13.54-36.35	18.88(3.12)	1.30(.07)	2.70(.15)	573	13.54-33.11	18.83(3.06)	548	13.72-36.35	18.94(3.19)
BMIz T0	1121	-2.47-3.89	.47(1.09)	.14(.07)	-.21(.15)	573	-2.47-3.11	.37(1.05)	548	-2.11-3.89	.57(1.11)
BMI T1	1022	13.87-38.51	19.56(3.40)	1.31(.08)	2.71(.15)	515	13.87-35.38	19.55(3.33)	498	14.29-38.51	19.58(3.50)
BMIz T1	1022	-2.52-3.91	3.91(.39)	.10(.08)	-.30(.16)	515	-2.52-3.78	.30(1.08)	498	-1.98-3.78	.50(1.14)
BMI T2	840	14.53-35.95	20.31(3.35)	1.20(.08)	1.93(.17)	420	14.53-35.69	20.35(3.29)	417	15.03-35.95	20.29(3.42)
BMIz T2	840	-2.39-3.45	.39(1.04)	.12(.09)	-24(.17)	420	-2.39-3.42	.30(1.09)	417	-2.31-3.45	.48(1.08)
Competence T0	1121	1.00-5.00	3.43(.86)	-.13(.07)	-.32(.15)	573	1.00-5.00	3.34(.87)	548	1.00-5.00	3.51(.84)[a]
Competence T1	1026	1.00-5.00	3.38(.92)	-.30(.08)	-.23(.15)	517	1.00-5.00	3.32(.92)	505	1.00-5.00	3.44(.91)[a]
Competence T2	929	1.00-5.00	3.31(.87)	-.28(.08)	-.14(.16)	481	1.00-5.00	3.21(.87)	443	1.00-5.00	3.41(.86)[a]
Autonomy T0	1121	1.00-5.00	3.27(.86)	-.28(.07)	-.31(.15)	573	1.00-5.00	3.27(.88)	548	1.00-5.00	3.27(.85)
Autonomy T1	1026	1.00-5.00	2.83(.81)	-.05(.08)	-.27(.15)	517	1.00-5.00	2.88(.82)	505	1.00-5.00	2.78(.79)
Autonomy T2	929	1.00-5.00	2.87(.80)	-.13(.08)	-.31(.16)	481	1.00-4.75	2.81(.82)	443	1.00-5.00	2.93(.78)[a]
Relatedness T0	1121	1.00-5.00	3.73(.83)	-.66(.07)	.24(.15)	573	1.00-5.00	3.69(.82)	548	1.00-5.00	3.77(.83)
Relatedness T1	1026	1.00-5.00	3.64(.81)	-.64(.08)	.38(.15)	517	1.00-5.00	3.62(.82)	505	1.00-5.00	3.65(.81)
Relatedness T2	929	1.00-5.00	3.56(.80)	-.50(.08)	.20(.16)	481	1.00-5.00	3.52(.80)	443	1.00-5.00	3.61(.79)
Intrinsic T0	1122	1.00-5.00	4.22(.87)	-1.28(.07)	1.23(.15)	573	1.00-5.00	4.16(.90)	549	1.00-5.00	4.29(.84)[a]
Intrinsic T1	1026	1.00-5.00	3.68(.93)	-.74(.08)	.07(.15)	517	1.00-5.00	3.64(.92)	505	1.00-5.00	3.71(.93)
Intrinsic T2	929	1.00-5.00	3.47(.92)	-.53(.08)	-.18(.16)	481	1.00-5.00	3.38(.94)	443	1.00-5.00	3.58(.89)[a]
Identified T0	1122	1.00-5.00	3.64(.90)	-.39(.07)	-.28(.15)	573	1.00-5.00	3.56(.87)	549	1.00-5.00	3.72(.92)[a]
Identified T1	1026	1.00-5.00	3.44(.90)	-.36(.08)	-.23(.15)	517	1.00-5.00	3.40(.85)	505	1.00-5.00	3.48(.95)
Identified T2	929	1.00-5.00	3.26(.91)	-.24(.08)	-.33(.16)	481	1.00-5.00	3.24(.89)	443	1.00-5.00	3.27(.93)
Introjected T0	1122	1.00-5.00	2.07(1.13)	.90(.07)	-.12(.15)	573	1.00-5.00	2.08(1.06)	549	1.00-5.00	2.07(1.19)
Introjected T1	1026	1.00-5.00	2.71(1.02)	.10(.08)	-.73(.15)	517	1.00-5.00	2.83(.99)[b]	505	1.00-5.00	2.59(1.03)
Introjected T2	929	1.00-5.00	2.48(.91)	.30(.08)	-.40(.16)	481	1.00-5.00	2.59(.91)[b]	443	1.00-5.00	2.36(.89)
External T0	1122	1.00-5.00	1.96(.95)	.92(.07)	.16(.15)	573	1.00-5.00	1.91(.89)	549	1.00-5.00	2.01(1.01)
External T1	1026	1.00-5.00	2.01(.91)	.94(.08)	.48(.15)	517	1.00-5.00	2.02(.90)	505	1.00-5.00	2.00(.93)
External T2	929	1.00-5.00	2.26(.94)	.58(.08)	-.32(.16)	481	1.00-5.00	2.30(.92)	443	1.00-5.00	2.22(.95)
Amotivation T0	1122	1.00-5.00	1.50(.70)	1.78(.07)	3.4(.15)	573	1.00-4.67	1.46(.66)	549	1.00-5.00	1.54(.73)[a]
Amotivation T1	1026	1.00-5.00	1.54(.69)	1.75(.08)	2.69(.15)	517	1.00-5.00	1.50(.65)	505	1.00-5.00	1.58(.72)[a]
Amotivation T2	929	1.00-5.00	1.67(.75)	1.46(.08)	2.28(.16)	481	1.00-5.00	1.65(.70)	443	1.00-5.00	1.68(.79)

Note: [a] demonstrates a statistically significant gender difference with boys' values being higher. [b] demonstrates a statistically significant gender difference with girls' values being higher.

Table 2. Estimation results for the final unconditional latent growth models for the psychological needs and motivational regulation

Estimates of parameters	Autonomy	Competence	Relatedness	Intrinsic	Identified	Introjected	External	Amotivation
Intercept (α_1)	3.19 (.03)	3.43 (.03)	3.73 (.04)	4.18 (.04)	3.64 (.03)	2.07 (.05)	1.93 (.03)	1.49 (.02)
Slope (α_2)	-.20 (.03)	-.06 (.02)	-.09 (.02)	-.38 (.03)	-.19 (.03)	.64 (.06)	.16 (.02)	.09 (.02)
Variances								
Level (ψ_{11})	.35 (.05)	.44 (.05)	.45 (.04)	.42 (.06)	.36 (.05)	.07 (.09)	.40 (.06)	.19 (.04)
Change (ψ_{22})	.09 (.02)	.09 (.02)	.08 (.02)	.10 (.03)	.11 (.03)	.23 (.10)	.10 (.03)	.05 (.01)
Covariance (ψ_{21})	-.08 (.03)	-.05 (.02)	-.09 (.03)	-.06 (.03)	-.05 (.03)	.13 (.12)	-.08 (.03)	-.02 (.01)
Error variances								
ε_1	.40 (.05)	.30 (.04)	.23 (.04)	.34 (.06)	.44 (.05)	.95(.07)	.52 (.08)	.29 (.04)
ε_2	.41 (.03)	.42 (.04)	.32 (.02)	.47 (.03)	.46 (.03)	.45 (.04)	.50 (.03)	.27 (.03)
ε_3	.27 (.04)	.20 (.03)	.24 (.04)	.27 (.07)	.25 (.06)	.59 (.04)	.40 (.07)	.26 (.05)
Fit of the model	$\chi^2(1) = 30.96$ $p < .001$ *CFI* = .88 *TLI* = .85 *RMSEA* = .209 90%, CI [.16, .26]	$\chi^2(1) = .01$ $p = .930$ *CFI* = 1.00 *TLI* = 1.00 *RMSEA* < .001 90%, CI [.00, .02]	$\chi^2(1) = .57$ $p = .449$ *CFI* = 1.00 *TLI* = 1.00 *RMSEA* < .001 90%, CI [.00, .07]	$\chi^2(1) = 29.46$ $p < .001$ *CFI* = .93 *TLI* = .88 *RMSEA* = .157 90%, CI [.11, .21]	$\chi^2(1) = .23$ $p = .629$ *CFI* = 1.00 *TLI* = 1.00 *RMSEA* < .001 90%, CI [.00, .06]	$\chi^2(0) = 00$ *Saturated model – Estimated Intro T2 value .66*	$\chi^2(1) = 9.64$ $p = .002$ *CFI* = .98 *TLI* = .93 *RMSEA* = .087 90%, CI [.04, .14]	$\chi^2(1) = 2.11$ $p = .146$ *CFI* = .99 *TLI* = .98 *RMSEA* = .031 90%, CI [.00, .09]

Note 1. The unstandardized solutions. Standard errors are in parentheses.
Note 2. *N*s = possible non-significance of estimated components.
Note 3. *F* = means of the latent components; ψ = variances of the latent components; ψ_{21} = covariance of the latent components; ε_1-ε_3 = residuals of the observed variables.

Table 3. Estimation results for the final conditional latent growth models for the psychological needs and motivational regulation with covariate effects

Estimates of parameters	Autonomy	Competence	Relatedness	Intrinsic	Identified	Introjected	External	Amotivation
Intercept (α_1)	3.19 (.03)	3.43 (.03)	3.73 (.04)	4.18 (.04)	3.64 (.03)	2.07 (.05)	1.93 (.03)	1.49 (.02)
Slope (α_2)	-.20 (.03)	-.06 (.02)	-.09 (.02)	-.38 (.03)	-.19 (.03)	.64 (.06)	.16 (.02)	.09 (.02)
Covariates								
Sex ⟶ α_1	*.04 (.07)*	-.12 (.04)	*-.04 (.05)*	*-.06 (.05)*	-.17 (.04)	*Saturated model – Estimated Intro T2 value .66*	*-.11 (.06)*	*-.11 (.07)*
Sex ⟶ α_2	*-.11 (.08)*	*-.08 (.10)*	*-.01 (.09)*	*-.08 (.15)*	*.12 (.12)*		*.13 (.18)*	*.09 (.30)*
BMIz→T0	*.01 (.04)*	*-.05 (.02)*	*-.06 (.03)*	*-.00 (.05)*	*.03 (.03)*		*.04 (.03)*	*.04 (.03)*
BMIz→T1	-.10 (.03)	-.11 (.03)	-.09 (.02)	-.07 (.03)	*-.02 (.03)*		*.03 (.03)*	.08 (.03)
BMIz→T2	-.02 (.04)	-.13 (.03)	-.08 (.03)	*-.06 (.04)*	*-.04 (.03)*		*.02 (.04)*	.11 (.02)
Variances								
Level (ψ_{11})	.35 (.07)	.42 (.05)	.42 (.03)	.41 (.06)	.37 (.05)	.18 (.25)	.33 (.06)	.15 (.05)
Change (ψ_{22})	.09 (.02)	.09 (.01)	.08 (.02)	.15 (.03)	.13 (.02)	.20 (.36)	.09 (.03)	.04 (.03)
Covariance (ψ_{21})	-.12 (.02)	-.07 (.02)	-.09 (.02)	-.09 (.03)	-.07 (.02)	.42 (.25)	-.05 (.03)	-.01 (.02)
Error variances								
ε_1	.35 (.05)	.26 (.04)	.19 (.03)	.23 (.06)	.40 (.05)	.85(.09)	.55 (.08)	.27 (.05)
ε_2	.38 (.03)	.41 (.03)	.30 (.02)	.46 (.04)	.44 (.03)	.57 (.04)	.50 (.04)	.27 (.04)
ε_3	.19 (.03)	.18 (.01)	.20 (.02)	.13 (.07)	.20 (.06)	.43 (.06)	.36 (.06)	.23 (.05)
Fit of the model	$\chi^2(8) = 12.34$	$\chi^2(8) = 6.11$	$\chi^2(8) = 2.01$	$\chi^2(8) = 10.22$	$\chi^2(8) = 3.21$	$\chi^2(7) = 3.66$	$\chi^2(8) = 5.92$	$\chi^2(8) = 8.59$
	p = 239	p = .582	p = .980	p = .238	p = .870	p = .812	p = .657	p = .382
	CFI = .98	*CFI* = 1.00	*CFI* = 1.00	*CFI* = .99	*CFI* = 1.00	*CFI* = 1.00	*CFI* = 1.00	*CFI* = .99
	TLI = .97	*TLI* = 1.00	*TLI* = 1.00	*TLI* = .99	*TLI* = 1.00	*TLI* = 1.00	*TLI* = 1.00	*TLI* = .99
	RMSEA = .038	*RMSEA* < .002	*RMSEA* < .001	*RMSEA* = .019	*RMSEA* < .001	*RMSEA* < .001	*RMSEA* < .001	*RMSEA* = .010
	90%, CI	90%, CI	90%, CI	90%, CI	90%, CI	90%, CI	90%, CI	90%, CI
	[.02, .06]	[.00, .04]	[.00, .01]	[.00, .05]	[.00, .03]	[.00, .04]	[.00, .03]	[.00, .05]

Note 1. The unstandardized solutions. Standard errors are in parentheses.
Note 2. F = means of the latent components; ψ = variances of the latent components; ψ_{21} = covariance of the latent components; ε_1-ε_3 = residuals of the observed variables.
Note 3. Non-significant covariate effects were italicized (Significance level α <.05).

Table 4. Summary of the regressive model main effects

Variables	$\beta(SE)$	p	Variables	$\beta(SE)$	p
Aut $\alpha_2 \rightarrow$ Int α_2	.66(.12)	< .001	Aut $\alpha_1 \rightarrow$ Int α_2	1.33(1.78)	.455
Aut $\alpha_2 \rightarrow$ Ident α_2	.47(.09)	<.001	Aut $\alpha_1 \rightarrow$ Ident α_2	.42(.86)	.623
Aut $\alpha_2 \rightarrow$ Ex α_2	-.28(.15)	.060	Aut $\alpha_1 \rightarrow$ Ex α_2	-1.17(1.83)	.524
Aut $\alpha_2 \rightarrow$ Am α_2	-.29(.13)	.029	Aut $\alpha_1 \rightarrow$ Am α_2	-2.09(3.33)	.531
Comp $\alpha_2 \rightarrow$ Int α_2	.37(.10)	< .001	Comp $\alpha_1 \rightarrow$ Int α_2	.02(21)	.916
Comp $\alpha_2 \rightarrow$ Ident α_2	.75(.09)	<.001	Comp $\alpha_1 \rightarrow$ Ident α_2	-.19(.14)	.168
Comp $\alpha_2 \rightarrow$ Ex α_2	-.14(.09)	.119	Comp $\alpha_1 \rightarrow$ Ex α_2	-.01(.26)	.962
Comp $\alpha_2 \rightarrow$ Am α_2	-.20(.12)	.104	Comp $\alpha_1 \rightarrow$ Am α_2	.08(.36)	.833
Rel $\alpha_2 \rightarrow$ Int α_2	.35(.15)	.021	Rel $\alpha_1 \rightarrow$ Int α_2	-.86(1.77)	.625
Rel $\alpha_2 \rightarrow$ Ident α_2	.23(.20)	.242	Rel $\alpha_1 \rightarrow$ Ident α_2	.13(.88)	.879
Rel $\alpha_2 \rightarrow$ Ex α_2	-.11(.16)	.505	Rel $\alpha_1 \rightarrow$ Ex α_2	.81(1.78)	.647
Rel $\alpha_2 \rightarrow$ Am α_2	-.45(.22)	.045	Rel $\alpha_1 \rightarrow$ Am α_2	1.58(3.35)	.638

Note: Aut = Autonomy, Comp = Competence, Rel = Relatedness, Int = Intrinsic motivation, Ident = Identified regulation, Ex = External regulation, Am = Amotivation.