

Original article

Motivational processes in physical education and objectively measured physical activity among adolescents

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Abstract

Purpose: Grounded in self-determination theory (SDT), the present study tested how students' perceptions of autonomy support from physical education teachers predicts objectively measured moderate-to-vigorous physical activity (MVPA) of adolescents. According to SDT, it was expected that psychological needs and autonomous and controlled forms of motivation would mediate these relationships.

Methods: Students ($n = 397$) aged from 11 to 15 years in 17 different schools filled in questionnaires regarding SDT variables. In addition, objective MVPA was measured using an accelerometer (ActiGraph GT3X; ActiGraph, Pensacola, FL, USA) for 7 days. Structural equation modelling was used to examine the hypothesized relationships among the study variables.

Results: The theory-based model showed a good fit with the data: $\chi^2 = 642.464$, $df = 257$; comparative fit index = 0.932; non-normed fit index = 0.921; root mean square error of approximation = 0.062; root mean square error of approximation 90% confidence interval: 0.054–0.067. As hypothesized, there was a significant and positive direct relationship between autonomy support and need satisfaction ($\beta = 0.81$, $p = 0.001$). In turn, need satisfaction positively predicted intrinsic motivation ($\beta = 0.86$, $p = 0.001$). Intrinsic motivation was positively related to MVPA ($\beta = 0.29$, $p = 0.009$). A significant indirect effect ($\beta = 0.20$, $p = 0.004$) supported the mediating role of psychological need satisfaction and intrinsic motivation in the relationship between perceived autonomy support and objectively measured MVPA.

Conclusion: The findings of the current study support the applicability of the SDT-based model in explaining the antecedents of objectively measured MVPA of adolescents. To enhance adolescents' daily MVPA, special focus should be put on increasing their intrinsic motivation toward physical education.

Keywords: Accelerometer; Motivation; Physical activity; Physical education; Self-determination theory

1. Introduction

Significant evidence suggests that physical activity (PA) is an important factor to prevent several diseases.¹ In addition, PA is associated with numerous health benefits among youth.² In comparison with light PA, moderate-to-vigorous PA (MVPA) is linked to many health benefits (e.g., better mental health and cardiorespiratory fitness, less fat gain) among adolescents.³ Nevertheless, evidence on PA indicates that, on average, one-half of European youths do not meet the recommended minimum of 60 min of MVPA (defined as ≥ 2296 counts/min⁴) per day.^{5,6}

Motivation toward MVPA is considered an important factor of MVPA engagement among youth.⁷ School physical

education (PE), where PE teachers play an important role in shaping students' motivation, functions as a feasible way to encourage adolescents' PA.⁸ Self-determination theory (SDT)⁹ has been used to explain the role of psychosocial and motivational factors on engagement in PA within the context of PE.^{10,11} However, only a few SDT-based studies have investigated the role of social factors (e.g., teachers' behavior), psychological needs and motivation in a PE context on objectively measured PA of adolescents.^{12–14} This study contributes to the existing literature by demonstrating the unique role of different types of motivation toward PE on objectively measured MVPA of adolescents, using SDT as the theoretical framework.

1.1. SDT

SDT, a theory of human motivation, has been widely used in educational settings,¹⁵ including PE.¹⁰ According to SDT,

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humans strive to satisfy the 3 basic psychological needs for autonomy (i.e., to experience behavior as volitional and independent), competence (i.e., to experience efficiency in action), and relatedness (i.e., to have sense of connection with the important others), which are complementary. Fulfilment versus thwarting of the psychological needs determines the quality of motivation and engagement in a particular activity.¹⁶

SDT distinguishes 4 types of motivational regulations depending on the level of autonomy that humans may have for participating in a given activity. These are intrinsic motivation (i.e., doing an activity for its inherent fulfilment rather than for a certain result), identified regulation (i.e., acting to acquire self-endorsed outcomes), introjected regulation (i.e., behaving out of a sense of obligation, guilt, or worry), and external regulation (i.e., acting to avoid sanctions or to receive a reward).¹⁷ These 4 forms of regulations fall along a continuum of self-determination, anchored by intrinsic motivation on 1 pole and external regulation on the other pole. According to SDT, fulfilling basic psychological needs in a given activity is proposed as central to the promotion of autonomous motivation (i.e., intrinsic motivation and identified regulation), whereas failing to satisfy these needs will likely result in controlled motivation (i.e., introjected and external regulations).¹⁶

According to SDT,⁹ autonomous forms of motivation have a positive association with the motivational outcomes (e.g., PA, health-related quality of life), whereas controlled forms of motivation reflect a negative association. Evidence regarding the associations between motivation and objectively measured PA, however, is contradictory. In line with the theory, Owen et al.¹⁸ stated that autonomous forms of motivation toward PE and leisure-time (LT) PA have a positive association with PA, whereas controlled forms of motivation have a negative association. Nonetheless, there are several studies reporting that no associations exist between controlled forms of motivation and objective PA among adolescents when measuring MVPA in PE¹⁹ and daily moderate-intensity PA.⁷

One of the central tenets of SDT is that social factors (e.g., autonomy-supportive behavior from significant others, such as teachers) can shape individuals' motivation toward a particular activity by satisfying their psychological needs.^{9,16} By acknowledging the students' feelings, providing them choices, and, at the same time, diminishing demands and avoiding punishments, teachers are likely to satisfy students' psychological needs.²⁰ An autonomy-supportive PE teacher would be interested in understanding how students manage a given exercise and also in providing them with additional help. Students would then most likely feel they could choose the way to continue (i.e., autonomy satisfaction), feel more positive about improving their skills (i.e., competence satisfaction), and feel that their teacher cares for them (i.e., relatedness satisfaction).¹¹ Studies in PE have shown that if PE teachers display autonomy-supportive behavior, then students typically report higher psychological need satisfaction, resulting in increased autonomous motivation toward PE.^{10,11,14}

1.2. Objectively measured PA within SDT

Most of the studies investigating the relationships between constructs within SDT have used self-reported measures to evaluate the level of PA.^{8,21,22} A recent meta-analysis demonstrated that students' perception of PE teachers' autonomy-supportive behavior has a positive correlation with students' self-reported PA, although the correlation was moderate (i.e., averaged correlation corrected for sampling and measurement error, $r=0.17$).²³ In addition, it has been shown that measuring MVPA using accelerometers versus self-report can produce considerably different results within the associations between PA and psychosocial variables.²⁴ For example, Kavanaugh et al.²⁴ found that psychosocial variables (e.g., PA enjoyment, PA self-efficacy) were significantly correlated only with subjectively measured PA, but not with objectively measured PA. Notwithstanding, previous research has shown that self-report measures and objective measures of PA are correlated ($r=0.39$, $p < 0.01$) among children²⁵ and adolescents (girls, $r=0.42$; boys, $r=0.46$).²⁶ Therefore, regardless of the PA method used, similar associations between psychosocial variables and PA should emerge.

The reasons for choosing self-reported measures over objective measures (e.g., accelerometer, heart rate monitors, pedometers, and doubly labeled water) might be that objective measures are more costly and time consuming. On the other hand, self-reported measures are considered more practical, have a lower participant burden, and are generally more accepted by study participants.²⁷ Self-report measures, however, can overestimate or underestimate true PA energy expenditure and rates of inactivity²⁸ because they are subject to different biases (i.e., social approval, social desirability, and inaccurate memory).²⁷

To best of our knowledge, only 3 cross-sectional studies^{12–14} have investigated the relationships between psychosocial and motivational variables (i.e., perceived autonomy support from significant others, fulfilment of basic psychological needs, and motivation) and adolescents' objectively measured PA. It has been found that perceived autonomy support from the PE teachers,^{12–14} parents,^{13,14} and peers¹⁴ is positively and significantly related to adolescents' psychological need satisfaction, which in turn is positively and significantly related to autonomous motivation. Importantly, autonomous motivation, expressed as a single measure of relative autonomy index (RAI), had a direct, significant, and positive association with objective PA measured by pedometers^{12,13} and accelerometers.¹⁴ The amount of the variance in objectively measured PA explained by psychosocial variables in these studies^{12–14,29} was relatively low, ranging between 1% and 9%.

It is important to note that none of the studies^{12–14} found a significant indirect effect between perceived autonomy support and objectively measured PA, mediated by psychological needs and autonomous motivation. The underlying reason for this might arise from using a single measure of RAI that could mask useful information when analyzing the

associations between motivation and objectively measured PA.³⁰ Various forms of motivation with different levels of autonomy could influence adolescents' engagement in PA. For example, Sebire et al.²⁹ have demonstrated that only intrinsic motivation mediates the relationship between psychological needs and objectively measured MVPA of children. The inclusion of each motivational regulation enables us to identify the magnitude and direction of these regulations that are associated with objectively measured PA. This information might provide us with deeper insight into adolescents' motives for engaging in PA.

1.3. The present study

All of these studies have significantly enhanced our understanding of the underlying psychosocial and motivational factors influencing objectively measured PA of adolescents. Nevertheless, the current study aims to extend previous work by demonstrating the unique effect of each motivational regulation on objectively measured MVPA. The current study, therefore, aims to explain the mechanism by which the perceived autonomy support from PE teachers is linked to students' objectively measured daily MVPA through psychological need satisfaction and different forms of motivation experienced in PE. The hypothesized model is depicted in Fig. 1. We expect that identifying specific pathways will further promote understanding of the processes by which adolescents' perception of the autonomy-supportive behavior of PE teachers is related to the adolescents' objectively measured MVPA.

Based on SDT and previous research we hypothesize that:

Hypothesis 1 (H₁): adolescents' perception of PE teachers' autonomy-supportive behavior would positively predict psychological need satisfaction in PE;

Hypothesis 2 (H₂): adolescents' psychological need satisfaction would positively predict intrinsic motivation and identified regulation, but inversely introjected and external regulation in PE;

Hypothesis 3 (H₃): intrinsic motivation and identified regulation in PE would positively predict the objectively measured MVPA of adolescents, whereas introjected and external regulation would inversely predict the objectively measured MVPA of adolescents;

Hypothesis 4 (H₄): adolescents' perceived autonomy support from the PE teacher is positively and indirectly related to the objectively measured MVPA of adolescents through psychological need satisfaction, intrinsic motivation, and identified regulation in PE.

2. Methods

2.1. Participants and procedures

The participants were 6th-, 7th-, and 8th-grade students recruited from 17 basic and secondary schools located in 3 different cities in Estonia. Informed assent forms were given to all 2201 eligible students and their parents, and 551 students agreed to participate. Students were eligible if they were 6th- to 8th-grade students without restriction on their participation in PE classes. Questionnaires were administered and accelerometers were used to gather data. Of the 551 participants, 3 were

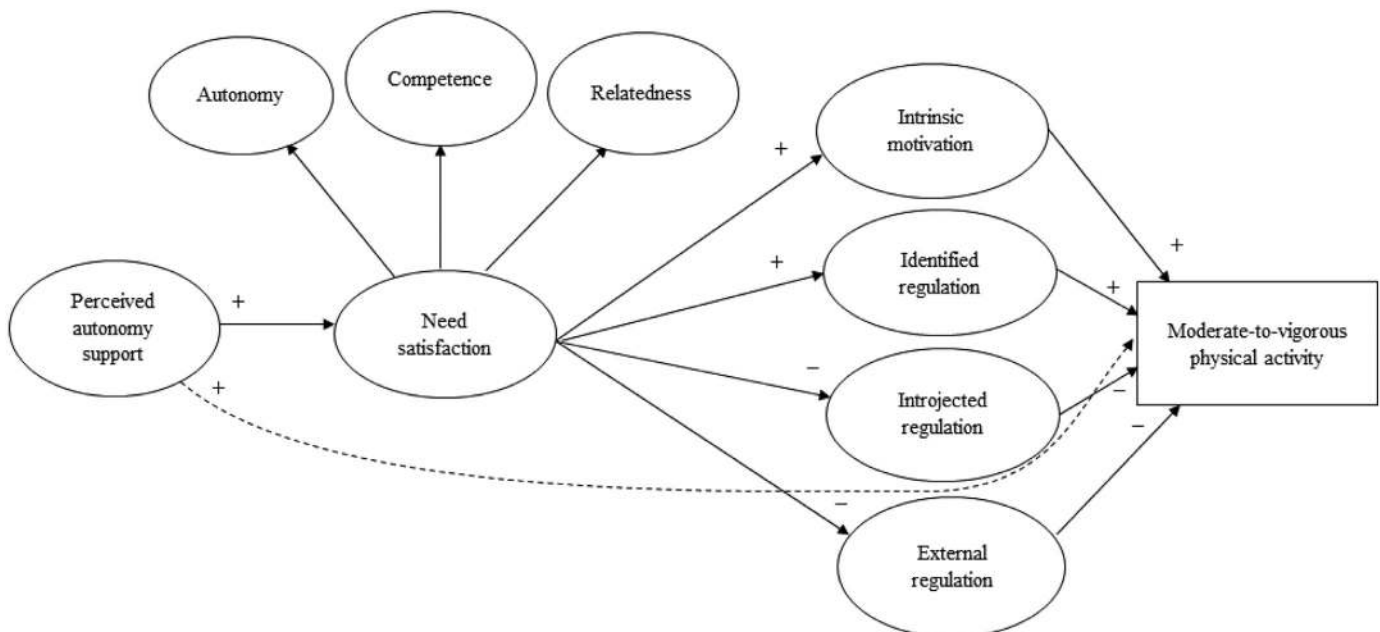


Fig. 1. Hypothesized model of the motivational processes. *Oval-shaped variables* represent latent variables, and *rectangular-shaped variables* represent manifest variables. *Solid lines* indicate significant relationships, and the *dotted line* indicates the path freed in the test of the model but hypothesized to be 0. For visual simplicity, covariances between different forms of motivation and indicators of the latent variables are not shown. "+" denotes a positive path; "-" denotes a negative path. Also, indirect effects from perceived autonomy support on motivational regulations through need satisfaction and from perceived autonomy support on moderate-to-vigorous physical activity through need satisfaction and motivational regulations were tested.

excluded owing to the loss of the accelerometer and 113 were excluded because their accelerometer data indicated that they did not wear the device for the required minimum of 10 h/day for a minimum of 4 days. Thus, the study sample comprised 435 participants ranging in age from 11 to 15 years (13.13 ± 0.92 , mean \pm SD). In total, there were 296 female (68.0%) and 139 male (32.0%) participants. All the study participants were middle-class white Europeans.

The current study was approved by the Ethical Committee of Tartu University. Relevant school administrators were asked to approve of their schools' participation in the study. Participants and their parents gave written informed consent for participation in the study. Two research assistants administered the questionnaires and ActiGraph GT3X (ActiGraph LLC, Pensacola, FL, USA). Students were asked to respond to the statements of the questionnaire honestly. After completing the questionnaires at school in a quiet classroom, each participant was given an ActiGraph GT3X (ActiGraph LLC) to wear for the next 7 days. Research assistants provided participants with verbal and written instructions regarding the accelerometer. The study participants were instructed to start wearing the device around their waist as soon as possible and to remove it only for sleeping and water-based activities. The students from 17 different schools completed all measures during the period from October 2017 to March 2018.

2.2. Measures

For 3 of the measures, students completed a questionnaire in which they responded, on a 7-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*) to statements related to each measure. The measures are described below.

2.2.1. Perceived autonomy support

The short form of the Perceived Autonomy Support Scale for Exercise Settings³¹ consists of 4 items and was used to measure students' perception of their PE teachers' autonomy-support behavior within PE class. An example item is: "My PE teacher listens to me about my PA." Previous studies have shown high internal reliability (composite reliability coefficient, $\rho = 0.92$)³¹ and have supported the factorial validity of the Perceived Autonomy Support Scale for Exercise Settings with adolescents in a similar age group in exercise settings³¹ and in the context of PE and LTPA.³²

2.2.2. Need satisfaction

Students' need satisfaction for autonomy, competence, and relatedness was assessed by 3 need satisfaction subscales from the Basic Psychological Need Scale and Need Frustration Scale,³³ adapted to PE.¹¹ Each subscale consisted of 4 items and was presented with a common stem, which read "During the PE lesson . . .", followed by a statement about the following set of items: need satisfaction for autonomy (e.g., ". . . I felt that the exercises reflect what I really want"), competence (e.g., ". . . I felt capable at what I did"), and relatedness (e.g., ". . . I felt that the class members I care about also cared about me"). Previous studies have shown that the Basic Psychological Need Scale and Need Frustration Scale is a valid and reliable measure

to use among adolescents in a similar age group in the context of PE³⁴ and among older adolescents in the context of PE.¹¹

2.2.3. Motivation in PE

The Perceived Locus of Causality Questionnaire (PLOCQ)³⁵ was used to assess students' motivation toward PE. The PLOCQ is an adaption of the Self-regulation Questionnaire adapted to the context of PE.³⁶ Each subscale consisted of 2 items and was presented with a common stem, which read "I do PE . . .", followed by statements about the following set of items: intrinsic motivation (e.g., ". . . because I enjoy PE"), identified regulation (e.g., ". . . because it's important to me to improve"), introjected regulation (e.g., ". . . I will feel bad about myself if I don't") and external regulation (e.g., ". . . because I must do it; it's the rule"). PLOCQ has been shown to be a valid and reliable measure to use among adolescents in a similar age group in the context of PE.^{8,12}

2.2.4. PA

Students' MVPA was measured using the Actigraph GT3X (ActiGraph LLC). The participants were assigned to wear the accelerometer on their waist for 7 consecutive days and to remove the device only for sleeping and water-based activities (e.g., bathing, swimming). The data files were downloaded using ActiLife software (Version 6.13.3; ActiGraph LLC). The sampling interval was set at 15 s. Accelerometer data were considered valid only if over 600 min (10 h) of recorded data per day for at least 4 days out of 7 were present. Zero counts of 60 consecutive min were classified as non-wear time. The PA intensity level as indicated by the accelerometers was measured using Evenson et al.⁴ cutoff points, which have been used to evaluate the level of PA during adolescence.³⁷ Evenson et al.⁴ cutoff points were used to calculate minutes spent in MVPA (≥ 2296 counts/min). The output of the accelerometer indicates average min of MVPA spent per day, weighted equally by each valid day.

2.3. Data analysis

All data analyses were conducted using SPSS Statistics (Version 23.0; IBM Corp., Armonk, NY, USA) and SPSS AMOS (Version 23.0; IBM Corp.). Data were screened for missing values and distributional properties.³⁸ Descriptive statistics and correlations for all study variables were computed, and Cronbach's alphas were calculated. A *t* test was performed to test differences between participants with and without valid accelerometer data.

Structural equation modelling based on maximum likelihood estimation with 5000 bootstrap samples^{39,40} was used to test the theory-based model specifying paths from perceived autonomy support to objectively measured MVPA through psychological needs and different forms of motivation (Fig. 1). In addition, a direct path from perceived autonomy support to MVPA, as well as covariances between all forms of motivation, was added. Given the complementarity of the basic psychological needs, the need for autonomy, competence and relatedness were subsumed into a single, higher-order construct.⁴¹ Specifically, 3 first-order latent factors (i.e., the need

satisfaction for autonomy, competence, and relatedness) that had their respective items as indicators served as indicators for a higher-order need satisfaction latent factor.

Next, the indirect effects from perceived autonomy support through basic psychological needs to different forms of motivations were estimated. In addition, 4 specific indirect effects from perceived autonomy support through basic psychological needs, and (a) intrinsic motivation, (b) identified regulation, (c) introjected regulation, and (d) external regulation to objectively measured MVPA were estimated. The bootstrap-generated, bias-corrected confidence approach was used to investigate the mediated relationships between study variables.^{39,40} 95% confidence intervals (CIs) were produced by bootstrapping with 5000 resamples. The specific indirect effect was considered statistically significant when the 95% CIs excluded 0.

The fit of the models was assessed by using the χ^2 goodness-of-fit statistics, Bentler-Bonett non-normed fit index (NNFI ≥ 0.90), comparative fit index (CFI ≥ 0.90), and root mean square error of approximation (RMSEA ≤ 0.08).⁴²

3. Results

3.1. Descriptive statistics

An initial inspection of the raw data revealed that out of 435 participants there were 5 univariate and 33 multivariate outliers. All subsequent analyses were conducted without these outliers, yielding a final sample of 397 participants. The sample of 397 participants ranging in age from 11 to 15 years (13.16 ± 0.91 years, mean \pm SD) composed of 277 female (69.8%) and 120 male (30.2%) participants.

Of the 397 participants who qualified for analyses (i.e., provided 4 valid days of accelerometer data), 42.07% ($n = 167$) provided 7 valid days of accelerometer data, 71.79% ($n = 285$) provided 6 valid days, and 91.69% ($n = 364$) provided 5 valid days. Participants' average accelerometer wear-time was 6.00 ± 1.26 days, with an average of 841.02 ± 63.99 min/day. On average, participants who provided 4 valid days of accelerometer data spent 58.39 ± 24.17 min in MVPA per day. Only 2.5% ($n = 10$) of the students met the 60 min MVPA/day

recommendation⁶ for 7 measured days, whereas 14.6% ($n = 58$) of the students did not meet the recommendation on any of the days. In addition, 17.4% ($n = 69$), 19.9% ($n = 79$), 19.4% ($n = 77$), 12.1% ($n = 48$), 8.3% ($n = 33$) and 5.8% ($n = 23$) of the students met the recommendation on 1, 2, 3, 4, 5, and 6 days, respectively.

There were no significant ($-1.77 \leq t \leq 1.65$) differences in any of the study variables between those with and without valid accelerometer data. However, we found a significant ($\chi^2 = 38.02, p < 0.0001$) difference in the proportion of boys and girls across those who did not provide valid accelerometer data (72 boys and 44 girls) and those who did provide valid accelerometer data (134 boys and 300 girls).

According to the sample size of the current study, observed power was found to be sufficient (*post hoc* power 0.99) assuming a given alpha level ($\alpha = 0.05$) and a modest ($R^2 = 0.07$) effect size.⁴³ Descriptive statistics, alpha coefficients for all measures, and correlations among latent study variables and MVPA are displayed in Table 1.

3.2. Main analyses

The measurement model of all 9 latent constructs and 25 indicators showed an acceptable fit with the data ($\chi^2 = 639.406, df = 252$; CFI = 0.932; Bentler-Bonett NNFI = 0.919; RMSEA = 0.062; RMSEA 95%CI: 0.056–0.068).

Next, we tested the hypothesized model specifying direct paths from perceived autonomy support to objectively measured MVPA through psychological needs and different forms of motivation. Fig 2 demonstrates that adolescents' perception of PE teacher's autonomy-supportive behavior predicted significantly and positively adolescents' perceived psychological need satisfaction (H_1). Adolescents' psychological need satisfaction in PE predicted significantly and positively all forms of motivation, except for external regulation, where the relationship between psychological need satisfaction and external regulation was significant and negative (H_2). From all forms of motivation, only intrinsic motivation predicted significantly and positively objectively measured MVPA (H_3). In this

Table 1
Descriptive statistics and correlations among latent study variables and MVPA.

Variable	Correlation						
	1	2	3	4	5	6	7
1. PE teacher autonomy support							
2. Need satisfaction	0.81**						
3. Intrinsic motivation	0.70**	0.86**					
4. Identified regulation	0.48**	0.60**	0.59**				
5. Introjected regulation	0.16*	0.20*	0.17*	0.51**			
6. External regulation	-0.11	-0.14	-0.25**	-0.05	0.50**		
7. MVPA	0.14*	0.19**	0.22**	0.10	0.01	0.03	
Mean	5.20	5.19	5.68	5.77	4.13	3.69	58.39
SD	1.19	1.11	1.51	1.22	1.74	1.68	24.17
α	0.78	0.93	0.88	0.78	0.68	0.62	N/A

Note: $n = 397$; MVPA was calculated in min/day.

* $p < 0.05$, ** $p < 0.01$.

Abbreviations: MVPA = moderate-to-vigorous physical activity; N/A = not applicable; PA = physical activity; PE = physical education.

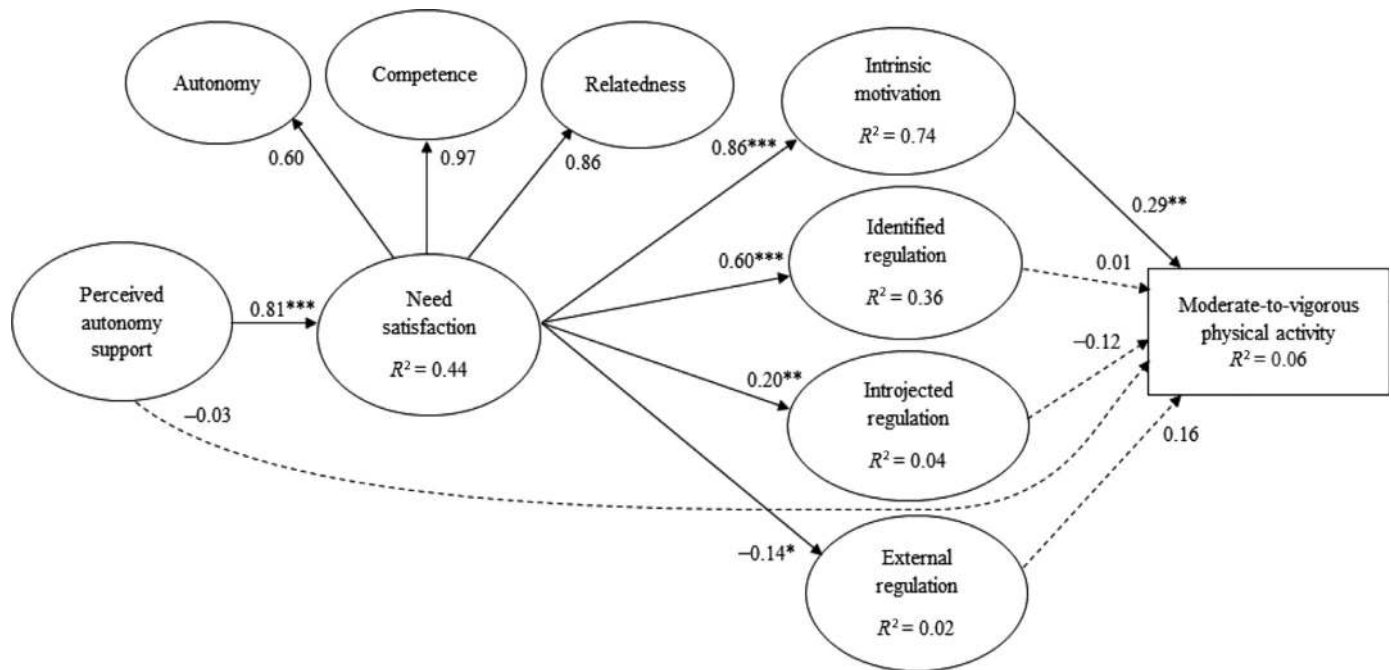


Fig. 2. The structural equation model measuring the relationships between perceived autonomy support and MVPA through need satisfaction and motivation. Four specific indirect effects of perceived autonomy support on MVPA were tested: (1) need satisfaction and intrinsic motivation, (2) need satisfaction and identified regulation, (3) need satisfaction and introjected regulation, and (4) need satisfaction and external regulation. In addition, 4 indirect effects of perceived autonomy on motivational regulations through need satisfaction were tested. *Solid lines* indicate significant relationships, and *dotted lines* indicate nonsignificant relationships. For visual simplicity, covariances between all forms of motivations are not shown. Covariances of the disturbance terms were: $r_{\text{intrinsic motivation-identified regulation}} = 0.17$, $r_{\text{intrinsic motivation-introjected regulation}} = 0.00$, $r_{\text{intrinsic motivation-external regulation}} = -0.25^{**}$, $r_{\text{identified regulation-introjected regulation}} = 0.50^{***}$, $r_{\text{identified regulation-external regulation}} = 0.05$, $r_{\text{introjected regulation-external regulation}} = 0.54^{***}$. $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

model, the direct relationship between perceived autonomy support and MVPA was nonsignificant.

Table 2 shows all the indirect effects that were tested in the current model. Significant and positive indirect effects of teachers' autonomy-supportive behavior on intrinsic motivation ($\beta = 0.70$, $p = 0.001$), identified regulation ($\beta = 0.48$, $p = 0.001$), and introjected regulation ($\beta = 0.16$, $p = 0.012$) through the psychological needs emerged. There was no significant indirect effect of autonomy-supportive behavior on external regulation ($\beta = -0.11$, $p = 0.066$) through the psychological needs.

Next, we tested specific indirect effects of teachers' autonomy-supportive behavior on MVPA. The only significant specific indirect effect of perceived autonomy support on MVPA was through perceived need satisfaction and intrinsic motivation ($B = 0.53$, $p = 0.004$) (H_4). There was no significant specific indirect effect through need satisfaction and identified regulation ($B = 0.02$, $p = 0.908$), through need satisfaction and introjected regulation ($B = -0.07$, $p = 0.269$), and through need satisfaction and external regulation ($B = -0.04$, $p = 0.200$) (Table 2). The structural equation model that was tested showed an acceptable fit with the observed data ($\chi^2 = 642.464$, $df = 257$; CFI = 0.932; Bentler-Bonett NNFI = 0.921; RMSEA = 0.062; RMSEA 90%CI: 0.054–0.067).

4. Discussion

The present study examined the role of adolescents' perception of their PE teachers' autonomy support on adolescents'

objectively measured MVPA through motivational processes in PE. The results of the current study found support for the model of motivational processes grounded in SDT and were mostly in line with the study hypotheses. Specifically, the results of the current study revealed that perceived autonomy support from the PE teachers fosters the fulfillment of adolescents' psychological needs (H_1). Psychological needs were, in turn, positively associated with intrinsic motivation, identified regulation, and introjected regulation, whereas they were negatively associated with external regulation (H_2). These results support the central tenets of SDT^{9,16} and have been corroborated by a number of previous studies.^{10,12–14,44} Of the motivational regulations, only intrinsic motivation was found to be positively and significantly related to objectively measured MVPA (H_3). Furthermore, it was found that psychological need satisfaction and intrinsic motivation mediate the relationship between adolescents' perceptions of autonomy support and objectively measured MVPA (H_4). The current study extends previous research^{12–14} by demonstrating the unique contribution of each motivational regulation on adolescents' MVPA within the motivational sequence. This finding enables researchers to better understand the associations between PE teachers' perceived autonomy support, adolescents' fulfillment of the psychological needs, motivation in PE, and objectively measured MVPA.

Consistent with past work,^{12–14} and as hypothesized (H_1), PE teachers' autonomy-supportive behavior positively predicted psychological need satisfaction. Moreover, results of the present

Table 2
Standardized (β) and unstandardized (B) direct and indirect effects of the latent study variables ($n = 397$).

Independent variable	Dependent variable	Mediator I	Mediator II	β	B (95%CI)
Direct effects					
Perceived autonomy support	Need satisfaction	—	—	0.81***	0.59*** (0.45 to 0.75)
Perceived autonomy support	MVPA	—	—	-0.03	-0.09 (-0.51 to 0.30)
Need satisfaction	Intrinsic motivation	—	—	0.86***	1.80*** (1.47 to 2.28)
	Identified regulation	—	—	0.60***	1.03*** (0.80 to 1.36)
	Introjected regulation	—	—	0.20**	0.40** (0.13 to 0.69)
	External regulation	—	—	-0.14*	-0.31* (-0.63 to -0.02)
Intrinsic motivation	MVPA	—	—	0.29***	0.50*** (0.19 to 0.80)
Identified regulation	—	—	—	0.01	0.03 (-0.39 to 0.46)
Introjected regulation	—	—	—	-0.12	-0.21 (-0.64 to 0.20)
External regulation	—	—	—	0.16	0.26 (-0.03 to 0.64)
Indirect effects					
Perceived autonomy support	Intrinsic motivation	Need satisfaction	—	0.70***	1.06*** (0.88 to 1.30)
	Identified regulation	—	—	0.48***	0.61*** (0.49 to 0.77)
	Introjected regulation	—	—	0.16*	0.24* (0.08 to 0.42)
	External regulation	—	—	-0.11	-0.18 (-0.37 to -0.02)
Specific indirect effect					
Perceived autonomy support	MVPA	Need satisfaction	Intrinsic motivation	0.20***	0.53** (0.22 to 0.87)
			Identified regulation	0.00	0.02 (-0.23 to 0.28)
			Introjected regulation	-0.02	-0.07 (-0.20 to 0.04)
			External regulation	-0.02	-0.04 (-0.16 to -0.00)
Sum of indirect effects					
Perceived autonomy support	MVPA	—	—	0.17***	0.46*** (0.78 to 0.21)
Total effect					
Perceived autonomy support	MVPA	—	—	0.14*	0.37* (0.13 to 0.61)

* $p < 0.05$, ** $p < 0.01$, *** $p \leq 0.001$.

Abbreviations: CI = confidence interval; MVPA = moderate-to-vigorous physical activity.

study and of previous studies conducted in a PE context^{10,11,12–14} supported one of the central tenets of SDT¹⁶: that the autonomy-supportive environment created by PE teachers is not directly related to autonomous motivation, but is instead related through the satisfaction of basic psychological needs.

As expected for H₂, the results of the current study showed that psychological need satisfaction is positively and significantly related to intrinsic motivation and identified regulation, which is in line with the SDT⁸ and with findings from previous studies in the field of PE.^{29,44} The magnitude of the associations of psychological need satisfaction with intrinsic motivation and identified regulation is consistent with previous studies conducted in PE.^{10,29} The variance of intrinsic motivation and identified regulation explained by the psychological need satisfaction is also comparable with the results reported by Standage et al.¹⁰ and Sebire et al.²⁹ The explained variance of intrinsic motivation, however, was the highest in the current study. A noteworthy finding emerged in the current study regarding the motivational processes embraced by SDT. Specifically, the results revealed a positive and significant association between the psychological needs and introjected regulation. This finding is not entirely surprising because previous studies have also shown a positive relationship with even greater magnitude between needs satisfaction and introjected regulation.^{10,29,45}

There are several possible explanations for this finding. First, as has been suggested, in the context of education the introjected regulation may not always be considered as maladaptive.⁴⁶ Ntoumanis⁴⁴ proposed that students may

participate in PE to avoid being isolated from other students. This is probably the case with the current sample and may explain the significant positive association between psychological needs satisfaction and introjected regulation. Second, students who rely on introjected regulation might be engaged in PE because they feel obliged to do so. They feel they should participate in PE because this is what “good students” do.¹⁰ Deci and Ryan¹⁶ have also stated that introjected regulation is especially interesting because the regulation is within the person, but at the same time is quite external to the self. Finally, the measurement of introjected regulation among young adolescents is demanding because it requires participants to recognize and comprehend feelings like guilt and shame as the origins of motivation. It could be argued that the concept of introjected regulation is too abstract for early adolescence because the development of personality is still incomplete and requires more advanced self-perception and cognitive development.^{47,48} This contradiction between the SDT and the findings of empirical studies needs further investigation.

The results from the current study revealed that only intrinsic motivation toward PE, but not identified regulation, is related to objectively measured MVPA of adolescents (H₃). The magnitude of the direct effect from intrinsic motivation on MVPA found in the current study is similar to the magnitude found in the study by Sebire et al.²⁹ In previous studies^{12–14} that used a composite score of autonomous motivation, a significant direct effect (β) from autonomous motivation on objectively measured PA has ranged between 0.10 and 0.19. The reason why intrinsic motivation, rather than identified regulation, would predict MVPA

might be that intrinsic motivation is a more autonomous form of motivation compared to identified regulation. Therefore, a significant relationship is more likely to emerge between intrinsic motivation and MVPA, as MVPA is considered as positive behavioral outcome.⁹ When examining the different forms of motivation, the intrinsic motivation is found to be the focal variable which leads to long-term PA engagement.²² The finding from the current study is in line with previous work among adolescents and children measuring daily PA^{29,49,50} and PA during PE lessons.⁴⁹ However, the findings in the study by Owen et al.⁴⁹ disagree with those from the current study in that Owen et al.⁴⁹ demonstrated a positive association between identified regulation and objectively measured PA during PE. In the current study, no association was found between students' identified regulation in PE and objectively measured MVPA. Several factors (e.g., LT PA motivation) might have influenced adolescents' daily MVPA.

According to the findings of the current study, we can state that interventions aimed at increasing adolescents' daily MVPA should have a special focus on increasing students' intrinsic motivation by offering them activities that they enjoy because they are fun. However, intrinsic motivation might not be the only predictor of objectively measured PA, as shown in previous studies.^{7,49} Therefore, other motivational factors, such as gaining health benefits (i.e., identified regulation)^{7,49} and avoiding guilt (i.e., introjected regulation) could also enhance adolescents' PA engagement.

The results of the current study demonstrate a nonsignificant relationship between introjected regulation and MVPA, and between external regulation and MVPA. Although the results from the few previous studies that have measured PA objectively among adolescents¹⁹ and adults⁷ are consistent with the results of the current study, a systematic review and meta-analysis by Owen et al.¹⁸ indicated that there was a significant negative, albeit weak, association between controlled forms of motivation and PA. One might argue that, in the presence of more autonomous motivation, the association between controlled forms of motivation and objectively measured MVPA would not be significant. The reason for this might be that the predictive power of the intrinsic motivation versus controlled forms of motivation on MVPA is much stronger, as has been shown previously.²⁹

In the current study, the model accounted for 6% of the variance in adolescents' objectively measured MVPA, which is similar to previous studies using objectively measured PA.^{13,14,29} There could be several reasons why psychological constructs fail to capture more variance in adolescents' objectively measured MVPA than was captured in the current and previous studies. First, adolescents' PA was measured only during a short period of time, which might not accurately reflect their everyday PA engagement. There may be several reasons, such as being ill, having extra school responsibilities (e.g., examination periods), or having different chores at home, as to why adolescents' PA during the study period might have deviated from their PA during a normal life period. Second, the current study evaluated adolescents' motivation in PE as a predictor of their daily MVPA, although there might be other factors, such as students' motivation toward LTPA, that could

also contribute to or detract from students' daily PA engagement. Studies using self-reported measures of PA, however, have mostly demonstrated higher predictive power of various psychological constructs on self-reported PA, ranging between 15% and 29% of explained variance.^{21,22} The difference in the variance explained by these 2 methods (i.e., self-report vs. objective PA measurement) could be due to participants overestimating their levels of PA in self-reported measures.²⁸ In addition, self-reports can be subject to recall bias, and therefore the information obtained can be inaccurate or misleading.⁵¹

The central aim of the present work was to identify specific pathways from students' perception of the autonomy-supportive behavior of their PE teachers to accelerometer-based PA through their psychological needs and different motivational regulations. Only 1 significant indirect pathway from perceived autonomy support to objectively measured MVPA through perceived satisfaction of the psychological needs and intrinsic motivation was identified (H₄). This is an important contribution of the current study to the extant literature because previous studies^{12–14} failed to demonstrate a significant indirect pathway from perceived autonomy support to objectively measured PA through motivational processes. The insignificant indirect effect found in these studies was probably due to using a composite variable of autonomous motivation¹⁴ or a single measure, namely the RAI.^{12,13} Keeping the motivational regulations separate enables us to explain the unique role of each regulation while predicting MVPA. The finding of the current study is consistent with the work by Zhang et al.,²² where it was shown that need support from PE teachers is positively related to students' psychological need satisfaction, intrinsic motivation in PE, and self-reported PA participation during time at school and out of school. Because the only significant pathway found in the current study was through intrinsic motivation, future interventions aimed at increasing adolescents' MVPA should be designed to enhance adolescents' pure enjoyment in engaging in PA rather than relying on other forms of motivational regulations.

Although the current study has several strengths, it is not without its limitations. Even though ActiGraph accelerometers have been shown to be valid for measuring the level of PA among children,⁴ it nevertheless has to be removed for aquatic activities and it does not measure MVPA accurately when subjects are cycling on a stationary bicycle or lifting weights. In addition, accelerometers do not provide information about the type of activity or the context in which the activity was done. Therefore, future studies could use accelerometer diaries when objectively measuring students' PA to collect more detailed information about the type of activities carried out while wearing them and during the periods when they are not worn. In addition to the use of objective PA instruments, self-reported measures could be incorporated into the data collection process to provide a more complete evaluation of adolescents' PA.

Because there was a significant difference in the proportion of boys and girls who provided valid accelerometer data and those who failed to provide it, the results of the current study are more generalizable to the girls than to the boys. In addition, the findings indicate that girls are more motivated to

wear the accelerometer than boys. Future qualitative research may provide information about the reasons boys are not as motivated as girls to take part in studies similar to ours.

Another limitation is the cross-sectional design of the current study, which does not allow causal inferences between the variables. Longitudinal studies are recommended to test reciprocal effects and to determine whether the model is consistent across time. The inability to capture more than 6% of the variance in MVPA suggests that other factors determining MVPA have not been evaluated. Future research should address this issue by evaluating LT motivation toward PA and by using constructs related to the theory of planned behavior to test the hypothesis of the trans-contextual model in predicting objectively measured PA. For example, in previous research by Barkoukis and Hagger,⁵² in which LT motivation toward PA and the theory of planned behavior constructs were added, the model accounted for 12.9% of the variance in self-reported PA behavior. Previous research has found that motivation connected to engagement in PE class could be transferred to motivation to engage in LTPA.²³

Future studies should evaluate the influence of perceived autonomy support from peers and parents on objectively measured MVPA through psychological needs and different motivational regulations. Furthermore, because PE teachers influence adolescents' LTPA in a more indirect way,²³ future work in the field should distinguish between PE and LTPA. In addition, collecting information regarding the overall social context in PE classes would be beneficial in assessing the relationships within the motivational sequence and adolescents' MVPA.

Finally, the current study focused particularly on explaining the "bright side" of adolescents' perception of PE teachers' behavior (i.e., autonomy supportive) and psychological needs (i.e., need satisfaction). However, to obtain more comprehensive insight into adolescents' motivational processes in relation to psychological experiences of adolescents in different social environments, the impact of adaptive and maladaptive behaviors of PE teachers and adolescents' experiences of both need satisfaction and need frustration should be explored. Future studies should investigate the influence on adolescents' perception of PE teachers' autonomy-supportive and controlling behavior concurrently, as well as adolescents' need satisfaction and need frustration, on autonomous and controlled forms of motivation and on their objectively measured MVPA.

5. Conclusion

The SDT-based model tested in the current study provides a framework that explains the antecedents of adolescents' objectively measured daily MVPA and emphasizes the importance of students' intrinsic motivation and fulfilment of their psychological needs within PE. The current study extends previous research in the field of PE by testing specific pathways from perceived autonomy support to objectively measured MVPA through psychological needs and different motivational regulations within the full motivational sequence. Future research in this area should include accelerometer diaries to provide additional information regarding adolescents' PA. Future studies

should also use longitudinal designs and consider other salient agents (e.g., peers, parents) as potential sources of autonomy support that may influence adolescents' objectively measured MVPA.

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Authors' contributions

HKT carried out the study, gathered the data, performed the statistical analysis, and drafted the manuscript; HT contributed to data collection, drafted the manuscript, and performed the statistical analysis; AK and VH drafted the manuscript and contributed to data analysis; LR designed the study and drafted the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

Supplementary materials

Supplementary data to this article can be found online at doi:10.1016/j.jshs.2019.06.001.

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