



OPEN Determinants of physical activity among female students based on the transtheoretical model

Maryam Abdoli¹, Leili Tapak²✉, Payam Amini³, Azam Geravandi⁴, Babak Moeini⁵, Omid Hamidi⁶ & Maryam Afshari⁷

This study investigates factors influencing physical activity based on the Transtheoretical model (TTM) among adolescents. This study was conducted on 745 individuals between the ages of 12 and 16 years and was analyzed using a generalized linear model (GLM) approach with appropriate link functions using both classical and Bayesian frameworks. The results show that in model 1, the probit link function is a more appropriate approach to determine the risk factors for physical activity. In model 2, the logit link function is a more appropriate approach to determine the risk factors for physical activity. In addition, this study highlights a positive association between theatrical relief (OR = 1.08; 95% CI 1.02, 1.14) and self-efficacy (OR = 1.06; 95% CI 1.02, 1.09) for physical activity, and a negative association between self-relief (OR = 0.82; 95% CI 0.74, 0.90), counter-conditioning (OR = 0.85; 95% CI 0.79, 0.92), stimulus control (OR = 0.87; 95% CI 0.81, 0.93) and helping relationships (OR = 0.94; 95% CI 0.88, 0.99) with physical activity among female students. Self-efficacy is crucial for predicting activity levels, suggesting beneficial interventions that combine physical activity with self-efficacy enhancement. Positive thinking and a structured behavior change process are essential for physical activity engagement.

Keywords Physical activity, Transtheoretical model, Ordinal logistic regression, Link function, Deviance information criterion

Despite advancements in health and medicine, the prevalence of non-communicable diseases (NCDs) is rising due to urbanization, unhealthy diets, and sedentary lifestyles¹. NCDs are major causes of disability and mortality, accounting for 65% of global deaths, with 80% occurring in low- and middle-income countries, and nearly 50% of these deaths happen before age 70^{2–4}. In Iran, over 83% of deaths were due to NCDs⁵, many of which could be prevented through healthy lifestyle choices (e.g., physical activity (PA))^{6,7}.

PA is crucial for public health, preventing and delaying various NCDs and premature mortality^{1,8}. The World Health Organization's initiative, "Active People for a Healthy World" (2018 to 2030)⁹ emphasizes the importance of PA in managing diseases like heart disease, diabetes, and obesity, while also enhancing mental well-being, cognitive function, quality of life, and overall wellness^{10–12}. PA is essential for all age groups. Nevertheless, developing healthy habits such as PA during childhood and adolescence is crucial, as it is easier to establish these behaviors during this growth period than later in life².

PA is especially essential for the health and well-being of female adolescents, yet many faces unique challenges that hinder their engagement in exercise. During this developmental stage, girls experience significant physical changes, such as the onset of menstruation, which can impact their body image and self-esteem. Research indicates that these factors contribute to a notable decline in PA among adolescent girls compared to their male peers. For instance, a systematic review highlighted that nearly 84% of middle school females engage in insufficient PA, with societal stereotypes often portraying physical activity as less feminine, leading to reluctance in participating in sports or exercise^{13,14}. Furthermore, studies have shown that the overall levels of PA decrease during adolescence, with girls consistently reported as being less active than boys^{15,16}. Addressing these

¹Department of Biostatistics, School of Public Health and Student Research Committee, Hamadan University of Medical Sciences, Hamadan, Iran. ²Department of Biostatistics, School of Public Health and Modeling of Noncommunicable Diseases Research Center, Hamadan University of Medical Sciences, Hamadan, Iran. ³School of Medicine, Keele University, Keele, Staffordshire ST5 5BG, UK. ⁴Department of Public Health, School of Public Health, Hamadan University of Medical Sciences, Hamadan, Iran. ⁵Department of Health Education, Health Sciences Research Center, Hamadan University of Medical Sciences, Hamadan, Iran. ⁶Department of Science, Hamedan University of Technology, Hamedan, Iran. ⁷Social Determinants of Health Research Center, Hamadan University of Medical Sciences, Hamadan, Iran. ✉email: l.tapak@umsha.ac.ir

barriers is crucial; a recent study found that support from peers, family, and teachers significantly influences PA participation among adolescent girls¹³. Encouraging physical activity in this vulnerable population is vital not only for improving physical health such as enhancing cardiovascular fitness and reducing obesity risk but also for fostering mental resilience and self-confidence. Thus, studying “determinants” or correlates of PA is an important prerequisite for designing relevant policies and effective programs. Recent studies indicate that the PA habits of adolescents are associated with factors from multiple domains, highlighting the importance of understanding these determinants in this age group (aged 12–16 years). A systematic review has shown that factors such as social support, self-efficacy, and demographic variables significantly influence PA habits among adolescents. Additionally, research highlights those older adolescents tend to engage in less physical activity, with socio-demographic factors playing a crucial role in shaping these habits¹⁷.

Human behavior is a complex interplay of various factors. Health education serves as the pivotal axis for health activities and programs. To ensure the effectiveness of these programs, a deep understanding of behavior and the influencing factors is essential. This knowledge enables the identification of existing behaviors that need to be changed or modified, and the introduction of new behaviors. The role of behavior study theories and patterns in health education is crucial in addressing these behavioral aspects¹⁸. Hence, selecting the right model or theory of health education is the initial step in understanding behavior. This foundational choice sets the stage for designing impactful interventions and strategies to promote positive behavioral changes¹⁹. PA is a multifaceted behavior that can be challenging to modify, and sustaining the new behavior poses its own set of difficulties. Therefore, leveraging behavior change models or theories is essential in facilitating the transformation of PA habits. These frameworks provide valuable insights and strategies to support individuals in not only adopting but also maintaining a physically active lifestyle²⁰.

One of the most effective models for understanding and predicting behavioral and cognitive changes related to the adoption of physical activity or exercise behavior is the Transtheoretical Model (TTM), developed by Prochaska and DiClemente²¹. The Transtheoretical Model (TTM) is recognized as one of the most comprehensive and integrated models for understanding behavioral changes in health. Initially applied to smoking cessation studies, it has since expanded to encompass healthy lifestyle promotion, including physical activity (PA)^{22,23}. This cyclical model describes behavior change as a dynamic process occurring over time, detailing a sequence of stages and processes through which individual's progress to adopt regular behavior. As a result, it has become one of the most popular models for understanding physical activity behavior²⁴.

Understanding the adoption and maintenance of exercise behavior in student girls is crucial, as their current levels of physical activity (PA) participation are insufficient compared to the benefits derived from regular exercise. The TTM offers a comprehensive framework for understanding how new habits are formed and maintained. It is one of the most effective models for behavior change, significantly impacting the promotion of PA. While TTM has been applied to various behaviors and age groups, there is still limited research focusing on promoting PA specifically among student girls. Also, acknowledging the challenges posed by physical inactivity and the pivotal significance of PA during adolescence, especially for female students who face a higher risk of conditions like osteoporosis, it becomes essential to pinpoint the factors influencing physical activity. Therefore, this theory-driven study was carried out to evaluate the determinants of PA based on TTM among first-year female high school students in Kermanshah city, Iran, with the aim of designing interventions that enhance their health and overall well-being.

Materials and methods

Study design and setting

This study was conducted to investigate the status of performing PA among first-secondary students in Kermanshah City, utilizing a cross-sectional study design.

This study was conducted on 745 individuals aged 12–16 years old, which was conducted using random sampling from three regions (3–2–1) using a multi-stage sampling method. A consent to participate was completed by all the individuals who wished to participate in this research. The students were given questionnaires for data collection (variables were provided in the supplementary file 1). The current study protocol was approved by the Ethics Committee of the Hamadan University of Medical Sciences. The Bioethics Committee of Hamadan University of Medical Sciences (IR.UMSHA.REC.1403.158) approved this study. All methods were performed in accordance with the relevant guidelines and regulations. Having a disease and physically and mentally disabling conditions were considered as the exclusion criteria. The ordinal response variable is PA with three levels (1 = Low PA, 2 = Medium PA, 3 = High PA). The independent variables were grade (1, 2, and 3), economic situation (weak, medium, good, and excellent), parental physical activity (yes/no), parents encourage PA (yes/no), places and equipment needed for PA (yes/no), interest in PA (yes/no), self-awareness, theatrical relief activities, environmental assessment, self-evaluation, self-release, countervailing conditioning to, stimulus control, helping relationships, reinforcement management, decision balance, self-efficacy, and social liberation (for details see supplementary file 1). Validity and reliability were evaluated by face and content methods. The results were presented in Table S1 (see supplementary file 1). According to the results, the content validity index as well as the content validity ratios for all subscales indicated an acceptable validity of the questionnaire. Moreover, the values of the Cronbach's alpha coefficient related to each subscale were greater than 0.7, indicating an acceptable reliability of the questionnaire.

Statistical analysis

Continuous and categorical basic characteristics of the subjects were presented as mean [standard deviation (SD)] and frequency (percentage) and compared between study groups using analysis of variance (ANOVA) or Chi-square tests.

The ordinal logistic regression model is specifically designed to analyze ordinal data. This model allows us to examine the effects of independent variables on an ordinal dependent variable. The main formula for this model is as follows:

$$\log \left(\frac{P(Y \leq j | X)}{P(Y > j | X)} \right) = \beta_0^{(j)} + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k$$

In the context of the ordinal logistic regression model, the following variables are defined: Y: The ordinal dependent variable that can take on different values, such as 1, 2, or 3. j: The current level of the dependent variable, which may be categorized as “low,” “medium,” or “high.” X: The vector of independent variables that influence the dependent variable.

$\beta_0^{(j)}$: The threshold parameters corresponding to each level of the dependent variable.
This formula indicates that the odds of being at or below level j compared to being above level j is a function of a linear combination of the independent variables. The coefficients β represent the effect of each independent variable on the probabilities associated with different levels.

For modeling, logit ($\log \left(\frac{\theta_k(X_i)}{1-\theta_k(X_i)} \right)$) and probit ($\phi^{-1} [\theta_k(X_i)]$) link functions were considered.
Moreover, models were fitted in Bayesian statistical paradigms. A p-value less than 0.05 is considered as significance. Assessment of models is based on deviance information criterion (DIC) for Bayesian models.

Results

Table 1 provides descriptive statistics for each of the 18 predictors used in this work. The results of the Chi-square test showed that between the levels of physical activity, in terms of grade, economic situation, parental PA, parents encourage PA, places and equipment needed for PA and interest in PA were significant difference ($P < 0.05$). The results of the ANOVA test showed that Mean values of increasing self-awareness, theatrical relief activities, environmental assessment, self-evaluation, self-release, countervailing conditioning to, stimulus control, helping relationships and social liberation were statistically significantly higher in high level of PA group

Variable	Category	Physical activity			p-value
		Low (n = 222)	Medium (n = 324)	High (n = 199)	
Grade	1	57 (25.7)	104 (32.1)	71 (35.7)	0.042
	2	73 (32.9)	119 (36.7)	70 (35.2)	
	3	92 (41.4)	101 (31.2)	58 (29.1)	
Economic situation	Weak	41 (18.5)	30 (9.3)	19 (9.5)	< 0.001
	Medium	101 (45.5)	152 (46.9)	84 (42.2)	
	Good	71 (32)	116 (35.8)	67 (33.7)	
	Excellent	9 (4.1)	26 (8)	29 (14.6)	
Parental physical activity	No	107 (48.2)	219 (67.6)	160 (80.4)	< 0.001
	Yes	115 (51.8)	105 (32.4)	39 (19.6)	
Parents encourage physical activity	No	189 (85.1)	305 (94.1)	192 (96.5)	< 0.001
	Yes	33 (14.9)	19 (5.9)	7 (3.5)	
Places and equipment needed for physical activity	No	85 (38.3)	190 (58.6)	140 (70.4)	< 0.001
	Yes	137 (61.7)	134 (41.4)	59 (29.6)	
Interest in physical activity	No	151 (68)	285 (88)	185 (93)	< 0.001
	Yes	71 (32)	39 (12)	14 (7)	
Increasing self-awareness		14.05 (3.94)	17.35 (3.71)	20.16 (3.89)	< 0.001
Theatrical relief activities		13.21 (3.88)	14.73 (3.56)	15.63 (3.83)	< 0.001
Environmental assessment		11.98 (3.29)	13.90 (3.02)	15.55 (2.76)	< 0.001
Self-evaluation		13.79 (3.97)	16.19 (3.18)	17.99 (2.34)	< 0.001
Self-release		9.35 (2.91)	11.87 (2.48)	13.78 (1.90)	< 0.001
Countervailing conditioning to		7.08 (2.86)	9.61 (2.65)	12.18 (2.55)	< 0.001
Stimulus control		6.83 (3.01)	9.85 (2.99)	12.40 (2.72)	< 0.001
Helping relationships		9.01 (3.56)	11.79 (3.09)	13.17 (2.77)	< 0.001
Reinforcement management		4.15 (1.36)	3.75 (1.44)	3.96 (1.63)	< 0.001
Decision balance		24.51 (6.09)	21.99 (5.20)	19.88 (6.31)	< 0.001
Self-efficacy		27.81 (6.11)	23.15 (5.82)	18.75 (7.14)	< 0.001
Social liberation		17 (4.20)	19.56 (3.51)	21.39 (3.51)	< 0.001

Table 1. Descriptive statistics of predictors that have been used in the present study. Categorical variables are presented as number (percentage) of respondents in a specific category of that variable and continuous variables are given as mean (standard deviation). The bold values indicate significant variables.

while mean value of reinforcement management, decision balance and self-efficacy were higher in Low level of PA group ($P < 0.001$) (Table 1).

The results of the ordinal regression model including OR (95% credible intervals) using Bayesian procedure with two link functions is presented in Table 2. In Bayesian model 1 with two link functions, the variables of grade, economic situation, parents encourage PA, places and equipment needed for PA, and interest in PA were significant. Also, In Bayesian model 2 with two link functions, the variables of grade, father Physical activity, places and equipment needed for PA, interest in PA increasing self-awareness, theatrical relief activities, self-release, counter vailing conditioning to, helping relationships, stimulus control, and self-efficacy were significant (Table 3).

Further, Table 4 provides the values of DIC; smallest value indicates the better fit model obtained through ordinal regression method using two link functions. In model 1, the smallest value of DIC through Bayesian ordinal regression model can be found under probit (1489) when compared to logit (1490) link functions. Furthermore; in model 2, the smallest value of DIC through Bayesian ordinal regression model can be found under logit (1172) when compared to probit (1178) link functions.

Discussion

The purpose of this study was to identify behaviors and factors associated with PA in adolescents. In accordance with the adequacy of the model and the estimated predictor values associated with the demographic variable within the framework of an ordinal regression model, two distinct methodologies, namely classical and Bayesian approaches, were employed. Our findings indicated that examining various link functions (probit, logit, etc.) can be useful; so that in the present study probit link function was a more suitable approach in determining PA risk factors in model 1, while in model 2, the logit link function was a more appropriate approach in determining the risk factors of physical activity.

These methodologies encompass the utilization of two distinct functional relationships connecting the variables pertaining to educational attainment, parental engagement in physical activities, availability of PA facilities, interest in physical activity, and the necessary equipment in model 1 and educational attainment, theatrical relief activities, self-release, countervailing conditioning to, stimulus control, helping relationships, and self-efficacy in model 2 with the target variable reflecting interest in physical activities.

The stages of behavioral change are a useful model for classifying people as active or inactive in terms of physical activity. The findings of the current investigation indicated that approximately 26.7% of the student cohort displayed high physical activity. In a separate study conducted by Mousavi et al., it was reported that merely 32% of female high school students residing in Tarem, Iran, engaged in physical activity²⁵. Adequate PA during the growing years has a major impact on a person's health in adulthood. There is great potential to improve health in this age group, and changes in PA patterns and lifestyle can have a significant impact on health outcomes in this age group²⁶.

People are more likely to engage in PA after considering the benefits of physical activity. It is necessary to make a leap in education and culture in the society, especially in the students who will be the future builders of the healthy society of tomorrow. Therefore, methods such as persuading students, informing the society through mass media, teaching useful and effective methods of physical activities, encouraging free time physical activities, promoting peer-led activities, providing educational materials, supporting students with disabilities, collaborating with parents and communities, and promoting peer-led activities in relation to free time to improve the level of activity physical fitness of students is recommended.

Predictor		Bayesian ordinal regression model with	
		Probit link (OR [95% CI])	Logit link (OR [95% CI])
Grade	1	ref	
	2	1.06 (0.87,1.30)	1.11 (0.78,1.55)
	3	1.35 (1.10,1.66)	1.67 (1.18,2.36)
Economic situation	Weak	ref	
	Medium	1.02 (0.77,1.34)	0.99 (0.62,1.60)
	Good	1.06 (0.79,1.43)	1.07 (0.64,1.80)
	Excellent	0.74 (0.50,1.10)	0.60 (0.30,1.18)
Parental physical activity	No	ref	
	Yes	1.54 (1.28,1.85)	2.05 (1.50,2.80)
parents encourage physical activity	No	ref	
	Yes	1.27 (0.91,1.78)	1.57 (0.89,2.80)
Places and equipment needed for physical activity	No	ref	
	Yes	1.55 (1.29,1.87)	2.09 (1.52,2.88)
Interest in physical activity	No	ref	
	Yes	1.99 (1.58,2.52)	3.23 (2.16,4.85)

Table 2. Effect size (95% confidence interval) of the risk factors for physical activity using Bayesian ordinal regression model. OR odds ratio, CI credible interval. The bold values indicate significant variables.

Predictor		Bayesian ordinal regression model	
		Probit link (OR [95% CI])	Logit link (OR [95% CI])
Grade	= 1	ref	
	2	1.01 (0.81,1.25)	0.98 (0.67,1.44)
	3	1.30 (1.04,1.63)	1.55 (1.05,2.29)
Parental physical activity	No	ref	
	Yes	1.12 (0.92,1.37)	1.17 (0.82,1.66)
Places and equipment needed for physical activity	No	ref	
	Yes	1.09 (0.89,1.32)	1.19 (0.85,1.68)
Interest in physical activity	No	ref	
	Yes	1.01 (0.77,1.32)	1.09 (0.68,1.75)
Increasing self-awareness		0.96 (0.93,0.99)	0.93 (0.88,0.98)
Theatrical relief activities		1.05 (1.01,1.08)	1.08 (1.02,1.14)
Environmental reassessment		0.98 (0.94,1.02)	0.96 (0.89,1.03)
Self-evaluation		0.99 (0.95,1.04)	0.99 (0.92,1.08)
Self-release		0.89 (0.74,0.94)	0.82 (0.74,0.90)
Countervailing conditioning to		0.92 (0.88,0.95)	0.85 (0.79,0.92)
Stimulus control		0.92 (0.89,0.96)	0.86 (0.81,0.93)
Helping relationships		0.96 (0.93,0.99)	0.93 (0.88,0.99)
Reinforcement management		0.97 (0.91,1.03)	0.95 (0.85,1.06)
Decision balance		0.98 (0.96,1)	0.97 (0.93,1.01)
Self-efficacy		1.03 (1.02,1.05)	1.05 (1.02,1.09)
Social liberation		1.01 (0.98,1.04)	1.01 (0.96,1.07)

Table 3. Effect size (95% confidence interval) of the risk factors for physical activity using Bayesian ordinal regression model 2 with two link functions. OR odds ratio, CI credible interval. The bold values indicate significant variables.

Model	Link function	Bayesian ordinal regression model
		DIC
1	Probit	1489
	Logit	1490
2	Probit	1178
	Logit	1172

Table 4. Model fit indices for Bayesian ordinal regression models with two link functions.

Our findings indicated that the chance of having higher levels of physical activities was significantly greater among grade 3 school girls compared to the grade 1. This result aligns with existing literature suggesting that increased age correlates with higher intrinsic motivation to participate in physical activities^{27,28}. Research has shown that intrinsic motivation, as defined by self-determination theory, plays a critical role in fostering sustained engagement in physical activities²⁹. To support this intrinsic motivation, it is essential to provide need support strategies that cater to children's psychological needs for autonomy, competence, and relatedness³⁰. However, some studies mention that PA behavior is formed in childhood and adolescence and does not change significantly with age³¹. Given that PA is one of the most important predictors of health, it is necessary to form PA behavior in adolescents so that it continues into adulthood.

The current study also found a positive relationship between self-efficacy and PA in female students. Self-efficacy refers to an individual's belief in their ability to successfully execute behaviors required to produce specific performance attainments. It is a cognitive concept that assesses how individuals perceive their capabilities in relation to behavioral needs. This belief is crucial as it links awareness and action, influencing motivation and persistence in engaging in physical activity^{32–34}. This means that by gradually passing through the stages, the self-efficacy of people to overcome the tempting situations of not doing PA and the obstacles caused by it increases. This finding is consistent with the findings of other studies^{35–38}. For people with low self-efficacy, receiving support from friends partially overcomes the lack of self-efficacy. In summary, the positive relationship between self-efficacy and PA in female students underscores the importance of integrating self-efficacy-enhancing strategies into physical education programs. By considering the mediating role of grit, educators can design more effective interventions to promote PA and overall well-being among college students. The current study also found a positive relationship between theatre relief activities and PA in female students. In terms of theatrical relief activities, there is limited research on their specific impact on PA in female students. However,

studies have shown that physical theater classes can have positive effects on mental health and well-being among college students, including reduced stress and anxiety³⁹. These classes often incorporate physical activities such as dance, aerial dance, and calisthenics, which can be beneficial for physical health and overall well-being.

In the study by Nefas et al., which examined the behavioral processes involved in physical activity, it was shown that reciprocal conditioning had the strongest relationship with PA in adolescents through its effect on self-efficacy⁴⁰, which is not consistent with our study.

In the current study, a negative correlation between helping relationships and PA of female students was observed, which is not consistent with Garcia's study. In Garcia's study, family support in younger adolescents was confirmed on adolescents' PA using structural equations⁴¹. Another study found that social support from peers and parents had a positive and direct effect on physical activity⁴². More studies in this field are needed to clarify how and the type of impact of social support in teenagers.

From these results, it can be concluded that creating a positive attitude towards the behavior and increasing awareness through credible and reliable sources can be a stimulus for performing health-oriented behaviors. On the other hand, the person himself has a very important role as someone who can effectively reinforce the behavior, providing educational services and access to these services in the form of social freedom is also very important in performing the behavior. This issue also overlaps completely with helping relationships⁴³.

One of the limitations of the study is the self-reporting of PA and other studied variables, despite the validity of the questionnaires, it may lead to inaccurate estimation of the results obtained. Therefore, future studies with observational and objective tools such as a pedometer are recommended. Another limitation of this study is that considering that the study sample was only girls, therefore, testing the differences in PA and its related factors according to gender. It is not comparable and the results cannot be generalized to all teenagers, and the third limitation of this study is due to the lack of access to students and the closure of schools during the Corona era, measuring the body mass index of students using the same and standardized tool was not used. The index was measured by parents through the video training given in the communication channel.

Conclusion

The results of this study indicate that construct of TTM including theatrical relief activities, self-release, countervailing conditioning to, stimulus control, helping relationships, and self-efficacy can play a major role in increasing female adolescents' physical activity.

These findings highlight the importance of a multifaceted approach to physical activity promotion that addresses both psychological and social factors influencing behavior.

Based on this study, we can conclude that the TTM is a valuable and appropriate behavior model for identifying factors aimed at acquiring and improving physical activity (PA) habits among student girls. Therefore, it is recommended to carry out this model in future studies to investigate the physical activity status in other age groups. Also, the results of this study can be used by health planners for future interventions.

Data availability

The data are available upon reasonable requests from the corresponding author.

Received: 6 July 2024; Accepted: 11 December 2024

Published online: 09 January 2025

References

- Phillips, S. M., Cadmus-Bertram, L., Rosenberg, D., Buman, M. P. & Lynch, B. M. Wearable technology and physical activity in chronic disease: opportunities and challenges. *Am. J. Prev. Med.* **54** (1), 144–150 (2018).
- Cumbie, S. A., Conley, V. M. & Burman, M. E. Advanced practice nursing model for comprehensive care with chronic illness: model for promoting process engagement. *Adv. Nurs. Sci.* **27** (1), 70–80 (2004).
- Ndubuisi, N. E. Noncommunicable diseases prevention in low-and middle-income countries: An overview of health in all policies (HiAP). *INQUIRY: J. Health Care Organ. Provis. Financ.* **58**, 0046958020927885 (2021).
- Liu, W. et al. Insufficient level of physical activity and its effect on health costs in low-and middle-income countries. *Front. Public Health* **10**, 937196 (2022).
- Yousefi, M. et al. Prevention and control of non-communicable diseases in iran: the case for investment. *Front. Public Health* **22** (1), 1248 (2022).
- WH O. A guide for population-based approaches to increasing levels of physical activity: implementation of the WHO global strategy on diet, physical activity and health (2007).
- Organization, W. H. Noncommunicable diseases country profiles 2014 (WHO, 2017).
- Shahbazzadeghan, B., Farmanbar, R., Ghanbari, A. & Roshan, Z. The study of the effects of the regular exercise program on the self-esteem of the elderly in the old people home of rasht. *Eur. J. Soc. Sci.* **13** (2), 271–277 (2010).
- WH O. *Global action plan on physical activity 2018–2030: more active people for a healthier world* (World Health Organization, 2018).
- WHO Health WHOR. *Medical eligibility criteria for contraceptive use: World Health Organization* (World Health Organization, 2010).
- Das, P. & Horton, R. Rethinking our approach to physical activity. *Lancet* **380** (9838), 189–190 (2012).
- Gakidou, E. et al. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* **390** (10100), 1345–1422 (2017).
- Duffey, K. et al. Barriers and facilitators of physical activity participation in adolescent girls: a systematic review of systematic reviews. *Front. Public Health* **9**, 743935 (2021).
- Stoeper, P., Biber, D., Davis, A., Welk, G. J. & Meyer, A. Contextualizing adolescent female physical activity behavior: a descriptive study. *Int. J. Environ. Res. Public Health* **20** (4), 3125 (2023).
- Eime, R. M. et al. Changes in sport and physical activity participation for adolescent females: a longitudinal study. *BMC Public Health* **16**, 1–7 (2016).

16. Okely, A. D. et al. Promoting physical activity among adolescent girls: the girls in sport group randomized trial. *Int. J. Behav. Nutr. Phys. Act.* **14**, 1–13 (2017).
17. van Sluijs, E. M. et al. Physical activity behaviours in adolescence: current evidence and opportunities for intervention. *Lancet* **398** (10298), 429–442 (2021).
18. Sharma, M. *Theoretical foundations of health education and health promotion* (Jones & Bartlett Learning, 2021).
19. Glanz, K., Rimer, B. K. & Viswanath, K. *Health behavior: Theory, research, and practice* (Wiley, 2015).
20. Noroozi, A., Tahmasebi, R. & Ghofranipour, F. Effect of health promotion model (HPM) based education on physical activity in diabetic women. *Iran. J. Endocrinol. Metab.* **13** (4), 361–367 (2011).
21. Prochaska, J. O. & DiClemente, C. C. Stages and processes of self-change of smoking: toward an integrative model of change. *J. Consult. Clin. Psychol.* **51** (3), 390 (1983).
22. Spencer, L., Adams, T. B., Malone, S., Roy, L. & Yost, E. Applying the transtheoretical model to exercise: a systematic and comprehensive review of the literature. *Health Promot. Pract.* **7** (4), 428–443 (2006).
23. Jiménez-Zazo, F., Romero-Blanco, C., Castro-Lemus, N., Dorado-Suárez, A. & Aznar, S. Transtheoretical model for physical activity in older adults: Systematic review. *Int. J. Environ. Res. Public Health.* **17** (24), 9262 (2020).
24. Prochaska, J. O., Redding, C. A. & Evers, K. E. The transtheoretical model and stages of change. *Health behavior and health education: Theory, research, and practice.* **4**, 97–121 (2008).
25. BashiriMoosavi, F., Farmanbar, R., Taghdisi, M. & AtrkarRoshan, Z. Level of physical activity among girl high school students in Tarom county and relevant factors. *Iran. J. Health Educ. Health Prom.* **3** (2), 133–140 (2015).
26. Horne, M., Tierney, S., Henderson, S., Wearden, A. & Skelton, D. A systematic review of interventions to increase physical activity among South Asian adults. *Public Health* **162**, 71–81 (2018).
27. Hsu, A. R. C., Nguyen-Rodriguez, S. T. & Spruijt-Metz, D. Age, physical activity motivation and perceived stress in minority girls. *Californian J. Health Prom.* **17**(2) (2019).
28. Dumith, S. C., Gigante, D. P., Domingues, M. R. & Kohl, H. W. III Physical activity change during adolescence: a systematic review and a pooled analysis. *Int. J. Epidemiol.* **40** (3), 685–698 (2011).
29. Kalajas-Tilga, H., Koka, A., Hein, V., Tilga, H. & Raudsepp, L. Motivational processes in physical education and objectively measured physical activity among adolescents. *J. Sport Health Sci.* **9** (5), 462–471 (2020).
30. Ahmadi, A. et al. A classification system for teachers' motivational behaviors recommended in self-determination theory interventions. *J. Educ. Psychol.* (2023).
31. Wu, T.-Y. & Jwo, J.-L. A prospective study on changes of cognitions, interpersonal influences, and physical activity in Taiwanese youth. *Res. Q. Exerc. Sport* **76** (1), 1–10 (2005).
32. Guicciardi, M. et al. Type 2 diabetes mellitus, physical activity, exercise self-efficacy, and body satisfaction. An application of the transtheoretical model in older adults. *Health Psychol. Behav. Med. Open Access J.* **2** (1), 748–758 (2014).
33. Heydari, H., Sharifirad, G. & Kamran, A. Assessment of physical activity status in patients with type 2 diabetes based on Transtheoretical model. *J. Health Syst. Res.* **10** (3), 429–441 (2014).
34. Parhizgar, Z., Mohammadi, M., Hashemian, M. & Rakhshani, M. Evaluation of physical activity of patients with prediabetes based on the transtheoretical model in Sabzevar, Iran in 2015. *J. Diabetes Nurs.* **4** (3), 73–82 (2016).
35. Mohammadi Zeidi, I., Ziaeiha, M., Khalaj, M., Mohammadi Zeidi, B. & Morshedi, H. Predicting the stages of change in physical activity behavior of QUMS students with Pender's model. *J. Inflamm. Dis.* **14** (3), 58–66 (2010).
36. Tamimi, H. & Noroozi, A. Determinants of physical activity in high school girl students: study based on health promotion model (HPM). *J. Health* **6** (5), 527–537 (2016).
37. Joseph, R. P., Royse, K. E., Benitez, T. J. & Pekmezci, D. W. Physical activity and quality of life among university students: exploring self-efficacy, self-esteem, and affect as potential mediators. *Qual. Life Res.* **23**, 659–667 (2014).
38. Hamilton, K., Warner, L. M. & Schwarzer, R. The role of self-efficacy and friend support on adolescent vigorous physical activity. *Health Educ. Behav.* **44** (1), 175–181 (2017).
39. Erickson, M. K. N. & Gremillion, A. Positive psychosocial experiences of a physical theater class among college students (2023).
40. Nefas, C. L. Physical activity relapse prevention in middle school students: Using mediation analysis (2013).
41. Garcia, J. M. et al. Social and psychological factors associated with adolescent physical activity. *J. Phys. Act. Health* **13** (9), 957–963 (2016).
42. de Farias Junior, J. C., Florindo, A. A., Santos, M. P., Mota, J. & Barros, M. V. Perceived environmental characteristics and psychosocial factors associated with physical activity levels in adolescents from Northeast Brazil: structural equation modelling analysis. *J. Sports Sci.* **32** (10), 963–973 (2014).
43. Kleis, R. R., Hoch, M. C., Hogg-Graham, R. & Hoch, J. M. The effectiveness of the transtheoretical model to improve physical activity in healthy adults: a systematic review. *J. Phys. Activity Health.* **18** (1), 94–108 (2020).

Acknowledgements

We would like to appreciate the Vice-chancellor of Education of the Hamadan University of Medical Science for technical support.

Author contributions

L.T. and M.A. conceived the research topic, explored that idea, performed the statistical analysis, and drafted the manuscript. P.A., A.G., B. M, M.A. and O.H. participated in the interpretations and drafting of the manuscript. All authors read and approved the final manuscript.

Funding

This study was supported and approved by Hamadan University of Medical Sciences (Grant NO: 140303082035).

Declarations

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

This study was submitted to and approved by the Ethical Committee of Hamadan University of Medical Science (IR.UMSHA.REC.1403.158). An informed written consent was obtained from the participants.

Additional information

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1038/s41598-024-83055-6>.

Correspondence and requests for materials should be addressed to L.T.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Open Access This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

© The Author(s) 2024