J Pediatr (Rio J). 2018;94(6):658–665

Jornal de Pediatria
www.jped.com.br

ORIGINAL ARTICLE

Biocultural approach of the association between maturity and physical activity in youth☆

André O. Werneck[a,*], Danilo R. Silva[b], Paul J. Collings[c], Rômulo A. Fernandes[d], Enio R.V. Ronque[a], Manuel J. Coelho-e-Silva[e], Luís B. Sardinha[f], Edilson S. Cyrino[a]

[a] *Universidade Estadual de Londrina (UEL), Grupo de Estudo e Pesquisa em Metabolismo, Nutrição e Exercício (GEPEMENE), Londrina, PR, Brazil*
[b] *Universidade Federal do Sergipe (UFS), Departamento de Educação Física, São Cristóvão, SE, Brazil*
[c] *Bradford NHS Foundation Trust, Bradford Institute for Health Research, Bradford, United Kingdom*
[d] *Universidade Estadual Paulista (UNESP), Departamento de Educação Física, Laboratório de Investigação em Exercício (LIVE), Grupo de Iniciação Científica Relacionado à Atividade Física (GICRAF), Presidente Prudente, SP, Brazil*
[e] *Universidade de Coimbra, Coimbra, Portugal*
[f] *Universidade de Lisboa, Faculdade de Motricidade Humana, Laboratório de Exercícios e Saúde, Lisbon, Portugal*

Received 14 June 2017; accepted 15 September 2017
Available online 13 November 2017

KEYWORDS
Adolescent;
Child;
Maturity;
Motor activity

Abstract
Objective: To test the biocultural model through direct and indirect associations between biological maturation, adiposity, cardiorespiratory fitness, feelings of sadness, social relationships, and physical activity in adolescents.
Methods: This was a cross-sectional study conducted with 1,152 Brazilian adolescents aged between 10 and 17 years. Somatic maturation was estimated through Mirwald's method (peak height velocity). Physical activity was assessed through Baecke questionnaire (occupational, leisure, and sport contexts). Body mass index, body fat (sum of skinfolds), cardiorespiratory fitness (20-m shuttle run test), self-perceptions of social relationship, and frequency of sadness feelings were obtained for statistical modeling.
Results: Somatic maturation is directly related to sport practice and leisure time physical activity only among girls ($\beta = 0.12$, $p < 0.05$ and $\beta = 0.09$, respectively, $p < 0.05$). Moreover, biological (adiposity and cardiorespiratory fitness), psychological (sadness), and social (satisfaction with social relationships) variables mediated the association between maturity and physical activity in boys and

☆ Please cite this article as: Werneck AO, Silva DR, Collings P, Fernandes RA, Ronque ER, Coelho-e-Silva MJ, et al. Biocultural approach of the association between maturity and physical activity in youth. J Pediatr (Rio J). 2018;94:658–65.

* Corresponding author.
E-mail: andreowerneck@gmail.com (A.O. Werneck).

https://doi.org/10.1016/j.jped.2017.09.008

for occupational physical activity in girls. In general, models presented good fit coefficients.
Conclusion: Biocultural model presents good fit and emotional/biological factors mediate part of the relationship between somatic maturation and physical activity.

PALAVRAS-CHAVE
Adolescente;
Criança;
Maturação;
Atividade motora

Abordagem biocultural da associação entre maturação e atividade física na juventude

Resumo
Objetivo: Testar o modelo biocultural por meio de associações diretas e indiretas entre maturação biológica, adiposidade, capacidade cardiorrespiratória, sentimentos de tristeza, relacionamentos sociais e atividade física em adolescentes.
Métodos: Este foi um estudo transversal feito com 1.152 adolescentes brasileiros com idades entre 10 e 17 anos. A maturação somática foi estimada por meio do método de Mirwald (pico da velocidade de crescimento). A atividade física foi avaliada por meio do questionário de Baecke (contextos ocupacional, lazer e prática de esportes). Foram obtidos o índice de massa corporal, gordura corporal (soma de dobras cutâneas), capacidade cardiorrespiratória (teste *shuttle run* de 20 metros), autopercepções de relação social e frequência de sensação de tristeza para modelagem estatística.
Resultados: A maturação somática mostrou-se diretamente relacionada à prática de esportes e à atividade física de lazer somente entre meninas ($\beta = 0,12$, $p < 0,05$ e $\beta = 0,09$, respectivamente, $p < 0,05$). Ademais, as variáveis biológicas (adiposidade e aptidão cardiorrespiratória), psicológica (tristeza) e social (satisfação com os relacionamentos sociais) mediaram a associação entre maturação e atividade física em meninos e para atividade física ocupacional em meninas. Em geral, os modelos apresentaram bons coeficientes de ajuste.
Conclusão: O modelo biocultural apresenta bom ajuste e fatores emocionais/biológicos mediam parte da relação entre maturação somática e atividade física.

Introduction

Physical inactivity is associated with several negative outcomes.[1] Recently, prospective evidence classified physical inactivity as one of the more costly and greatest cause of deaths worldwide,[1] being a public health problem. Although physical inactivity affects most population groups,[2] the transition between childhood and adolescence appears be a critical period regarding cessation of active behaviors, such as overall physical activity or sport practice,[2] and increases in sedentary behavior,[3] which have a moderate tracking to adulthood.[4] In this sense, according to the guidelines (at least 60 min of moderate to vigorous physical activity daily), the prevalence of physical inactivity worldwide is high.[5] In Brazil, the rates of physical inactivity are approximately 60% among boys and 75% among girls, considering 300 min of physical activity per week as physically active.[6] Thus, understanding the determinants and correlates of different domains of physical activity at these ages is an important research field in order to propose health intervention with medium to long-term effects.

The main focus of determinants and correlates to physical activity in youth are gender, psychosocial, social, and environmental factors, but less attention has been given to important biological changes that occur during this phase.[3] Adolescents of the same chronological age can be under different biological rhythms, which influence physical, psychological, social, and perceived environment variables related to physical activity.[4] However, different biological factors can also influence physical activity.[7,8]

During growth years, an important factor is biological maturation, which is the process toward mature state that influences several organic systems.[9] Earlier biological maturation is associated, through several possible mediators, with greater adiposity and cardiovascular and behavioral risk factors, especially among girls, in whom adiposity growth is the greatest mark of puberty.[9,10] Specifically, earlier biological maturation is associated with a lower level of physical activity.[11] However, the association appears to be predominantly indirect, especially considering psychological factors.

In this sense, a biocultural approach of the relationship between biological maturation and physical activity was proposed, aiming to integrate social, intra-personal, biological, and behavior factors into the same model through structural equation modeling approaches.[4] Three studies[12–14] have tested this model in British girls and found significant associations between maturity and physical activity mediated through interpersonal/psychological constructs, such as body image, self-conception, and self-efficacy. However, even more feasible pathways, involving social and other

biological factors (such as obesity[8] and fitness[15,16]), are possible and have not yet been assessed.

Therefore, more complex interactions between biological, psychological, and environmental correlates in young individuals of both sexes are warranted. Thus, the study aimed to test the biocultural model through direct and indirect associations between biological maturation, adiposity outcomes, cardiorespiratory fitness, feelings of sadness, perceived social relationships, and physical activity in adolescents. The hypothesis was that the association between biological maturation and physical activity is mediated by biological and psychological factors, validating the biocultural model.

Methods

Sample

This was a cross-sectional epidemiological school-based study in Brazilian adolescents aged between 10 and 17 years, enrolled in public schools of Londrina/PR. The city in which the study was conducted has 506,701 inhabitants, a mean human development index of 0.778, and a gross domestic product per capita of US$8530.77.[17]

Sample recruitment was performed in two stages. First, all public schools of the city were separated into regions (north, south, east, west, and downtown) and two schools were randomly selected from each location. Subsequently, classes of those schools were randomly selected and all students within classes were invited to participate in the study. Adolescents using prescription medicine, undergoing treatment for an illness, or who failed to return a consent form signed by parents were ineligible. Recruitment peaked at 1,395 adolescents, but 243 failed to provide all required data for the analysis and were excluded due to missing data. The analysis of missing data from this sample has been published elsewhere.[8] The local ethics committee, in accordance with the Helsinki declaration, approved all procedures. An informed consent was obtained from all participants and their parents.

Procedures

Data collection was performed at the school setting. The research team, composed by trained undergraduate and graduate students, remained in each school for one week. In the first two days, subjects were invited to participate; the consent form was delivered and collected. In the last three weekdays, assessments were performed in the same order in all 10 schools.

Measures

Physical activity

The Baecke questionnaire[18] was self-completed by adolescents (guided by a trained assessor) and used as an indicator of current physical activity level. This instrument contains questions about the intensity and time of practice. It gives specific scores for each physical activity domains (occupational, leisure time and sports), which were treated as different patterns of physical activity. The intra-class correlation coefficient (ICC) of the questionnaire was 0.73, which is considered moderate to good.[19]

Biological maturation

Biological maturation was estimated through somatic maturation derived from estimated age at peak of height velocity, using the algorithm proposed by Mirwald et al.[20] This method estimates distance in years from peak height velocity through anthropometric variables (stature, sitting height, leg length, and body mass). The prediction of age at peak height velocity was determined by subtracting the maturity-offset from chronological age.

Adiposity indicators

Nutritional status was obtained through body mass index (BMI) with the formula: kg/m^2, and the following values were considered as technical error of measurement (TEMs): weight = 0.68% and height = 0.37%. Body fat was assessed through subscapular and tricipital skinfold thickness, which were measured by a trained evaluator using a Lange® caliper (precision = 0.5 mm), according to the recommendations of Harrison et al.[21] The TEMs were 4.8% and 3.5% for subscapular and tricipital skinfolds, respectively.

Cardiorespiratory fitness

Participants performed the 20-meter shuttle-run test proposed by Leger and Lambert.[22] The protocol was administered in indoor courts of the schools. Based on the test times achieved, peak VO_2 was estimated in $ml\,kg^{-1}\,min^{-1}$, according the equations proposed by Léger et al.[23]

Psychological variables

Sadness feelings were assessed through the Likert-type question: ''How often you feel sad or depressed?;'' options ranged from ''rarely'' to ''very frequently'', in four possibilities, and ICC of 0.62 was observed. In addition, self-perception about friends', families', and teachers' relationship were assessed through a questionnaire. Specifically, the Likert-type questions were: ''Regarding your relationship with your classmates and friends, you are;'' ''Regarding your relationship with your family, you are;'' and ''Regarding your relationship with your teachers, you are:''. Options ranged from ''very satisfied'' to ''very unsatisfied,'' with four possibilities; and the ICCs were, respectively, 0.50, 0.53, and 0.69. All ICCs for psychological variables were considered moderate to good.[19]

Statistical analyses

Descriptive statistics (mean, minimum, and maximum) were used to describe the characteristics of the sample. Subsequently, to analyze the association between variables, Pearson's correlation test was used, using SPSS software (IBM SPSS Statistics for Windows, version 22.0. NY, USA).

Structural equation modeling was used to verify associations between biological maturation, biological variables (adiposity and cardiorespiratory fitness), feelings of sadness, perceived social relationships, and physical activity. The parameters were estimated by the maximum-likelihood method, using AMOS software (Amos, version 22, IBM SPSS, IL, USA). The results were presented as beta

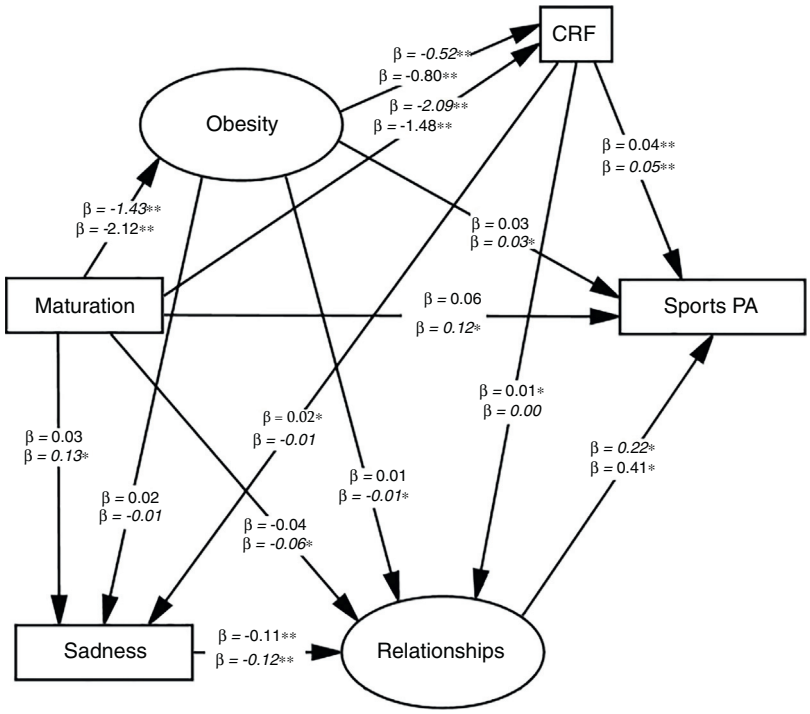

Figure 1 Final model for the association between biological and behavioral factors and sports practice by sex. Data in italics refer to girls. Fit parameters for boys: $\chi^2 = 20.64$ ($p = 0.242$); $\chi^2/df = 1.21$; RMSEA = 0.02; CFI = 0.99; TLI = 0.99. Fit parameters for girls: $\chi^2 = 21.74$ ($p = 0.195$); $\chi^2/df = 1.28$; RMSEA = 0.02; CFI = 0.99; TLI = 0.99. *$p < 0.05$; **$p < 0.001$. χ^2, Chi-squared; df, degrees of freedom; RMSEA, root mean square of approximation; CFI, comparative fit index; TLI, Tucker–Lewis index.

regression coefficients (β). To estimate the overall fit of the model, the following parameters were used: Chi-squared test (χ^2), χ^2/degrees of freedom (df), root mean square of approximation, comparative fit index, and Tucker–Lewis index (TLI). Values <3.0 for χ^2/df, <0.08 for root mean square of approximation, >0.95 for comparative fit index, and >0.95 for TLI indicated acceptable adjustment.

The theoretical model is described in Fig. 1. The most distal exogenous variable was biological maturation, which is mediated by social relationships variables (perception of social relationships, sadness and stress) and biological variables to reach physical activity as the theoretical outcome. Moreover, the models were stratified by sex. A significance level of 95% was adopted to indicate significant associations.

Results

The final sample of the study comprised 1,152 adolescents aged between 10 and 17 years. The participants of this study presented a mean chronological age of 13 ± 1.4 years, with no statistical difference (between boys and girls $p > 0.05$). Age of peak height velocity was 12 ± 0.7 and 14 ± 0.7 years, respectively, for girls and boys (with significant differences, $p < 0.001$). In crude correlation analyses (Table 1), somatic maturation was not correlated with physical activity patterns in both sexes ($p > 0.05$). Similarly, adiposity indicators were only correlated with occupational physical activity in girls ($p < 0.05$). Sadness and perception of relationships were correlated with occupational physical activity in both sexes ($p < 0.05$), except with family and friends for boys.

In the main analyses, structural equation models were conducted for three physical activity domains (Fig. 1, sports; Fig. 2, occupational; and Fig. 3, leisure), which were in general fitted to the data according to χ^2/df, root mean square error of approximation, comparative fit index, and Tucker Lewis index. Two latent variables were included in the models: adiposity (body mass index and sum of skinfolds) and perception of relationships (with family, teacher, and friends). Somatic maturation was only directly associated with physical activity in leisure and sports patterns in girls. Social relationships' perception was directly associated with sports practice in both sexes, but was inversely associated with occupational physical activity in girls. Cardiorespiratory fitness was directly associated with physical activity in all domains, except for boys in leisure physical activity. Furthermore, adiposity indicator was associated with sports practice in girls and occupational and leisure physical activity in boys.

Discussion

The current study aimed to test the biocultural model through direct and indirect associations between biological maturation and different domains of physical activity in Brazilian boys and girls. The main findings were that: (1) somatic maturation was directly associated with physical activity only in girls (leisure time and sports); (2) social relationships mediated the association between maturation

Table 1 Crude correlations between main variables according to sex.

	1	2	3	4	5	6	7	8	9	10	11
Boys (n = 512)											
1. Age of peak height velocity	1.00										
2. Body mass index	−0.37[a]	1.00									
3. Sum of skinfolds	−0.39[a]	0.84[a]	1.00								
4. Cardiorespiratory fitness	−0.02	−0.41[a]	−0.47[a]	1.00							
5. Sadness	−0.01	0.05	0.02	0.08	1.00						
6. Relationship with family	−0.08	0.02	0.06	0.03	−0.21[a]	1.00					
7. Relationship with friends	−0.07	0.04	0.06	0.08	−0.06	0.25[a]	1.00				
8. Relationship with teacher	−0.10[a]	−0.02	0.01	0.03	−0.10[a]	0.19[a]	0.13[a]	1.00			
9. Physical activity at sports	0.01	0.03	−0.02	0.19[a]	−0.03	0.09[a]	0.09[a]	0.02	1.00		
10. Occupational physical activity	0.03	0.06	0.03	0.07	0.10[a]	−0.08	0.02	−0.15[a]	0.21[a]	1.00	
11. Leisure time physical activity	0.00	−0.06	−0.15[a]	0.15[a]	−0.02	−0.00	0.07	−0.04	0.32[a]	0.10[a]	1.00
Girls (n = 640)											
1. Age of peak height velocity	1.00										
2. Body mass index	−0.24[a]	1.00									
3. Sum of skinfolds	−0.25[a]	0.88[a]	1.00								
4. Cardiorespiratory fitness	−0.24[a]	−0.37[a]	−0.40[a]	1.00							
5. Sadness	0.14[a]	−0.04	−0.02	−0.08	1.00						
6. Relationship with family	−0.10[a]	−0.12[a]	−0.09[a]	0.11[a]	−0.25[a]	1.00					
7. Relationship with friends	−0.11[a]	−0.01	−0.02	0.02	−0.11[a]	0.32[a]	1.00				
8. Relationship with teacher	−0.08	0.03	−0.01	0.02	−0.16[a]	0.20[a]	0.07	1.00			
9. Physical activity at sports	−0.01	−0.00	0.01	0.19[a]	0.02	0.08[a]	0.07	0.00	1.00		
10. Occupational physical activity	0.07	−0.08[a]	−0.08	0.10[a]	0.18[a]	−0.07	−0.08[a]	−0.11[a]	0.29[a]	1.00	
11. Leisure time physical activity	0.01	−0.01	−0.02	0.07	−0.01	0.06	0.07	0.02	0.29[a]	0.03	1.00

Note: Higher values of age of peak height velocity indicate late maturation. Higher values of sadness and social relationship are positive (rarely sad and very satisfied with relationship).

[a] $p < 0.05$.

and two domains of physical activity (sport and occupational) in boys and the sport domain in girls; (3) adiposity mediated the relationship between maturation and sport (girls), occupational and leisure physical activity (boys); and (4) the analyzed association (maturation and physical activity) is mediated by cardiorespiratory fitness with regard to sport and occupational physical activity for both sexes and to leisure physical activity among girls. Finally, the interactions between possible mediators of the association between somatic maturation and physical activity (feelings of sadness, perceived social relationship, adiposity, and cardiorespiratory fitness) should be highlighted in order to understand the complexity of prediction of some behaviors.

Physical activity is a behavior with several determinants.[24] Evidences show that individual, social, and environmental factors can explain some domains of physical activity in young individuals from different places differently worldwide.[24] Thus, Cumming et al.[7] proposed a biocultural approach, including intra-personal and social variables as well as biological factors to examine the determinants of physical activity and, particularly, the relationship between biological maturation and physical activity, which can be mediated by social/cultural, psychological, and biological factors.

The current study found a direct and positive relationship between somatic maturation and sports and leisure time physical activity in girls. In other words, girls with late maturation had greater physical activity levels. Considering that biological maturation is related with several changes in the neuroendocrine system of adolescents, a possible explanation for this finding can be in the organic biology of female sex itself. One of them is the regulation of dopamine secretion, which is related to pleasure and motivation for physical activity and exercise practice.[25] As girls tend to mature in average two years earlier than boys, dopamine sensitivity could suffer an impact and, consequently, physical activity would become less pleasant.[9] Additionally, intrapersonal characteristics that were not monitored in the present study, such as body image, sexuality, self-efficacy, and motivation to be active, which are related to both maturity and physical activity, can be involved in the observed association.[26]

Apart from the direct association, the greatest part of the effect of somatic maturation on physical activity appears to be indirect, through possible mediators. The present findings support biological and social pathways between somatic maturation and physical activity. Firstly, it was observed that somatic maturation had influenced biological outcomes, which are associated with physical activity. Specifically, adolescents who matured early showed greater adiposity and fitness, which were associated with physical activity (the outcome).

Differences between boys and girls were expected in the present study. Among girls, the increase in body fat that is associated with reproductive function during puberty (among other systems), is clear and appears to negatively influence cardiorespiratory fitness. In contrast, boys tend to present an improvement in lean mass during puberty and

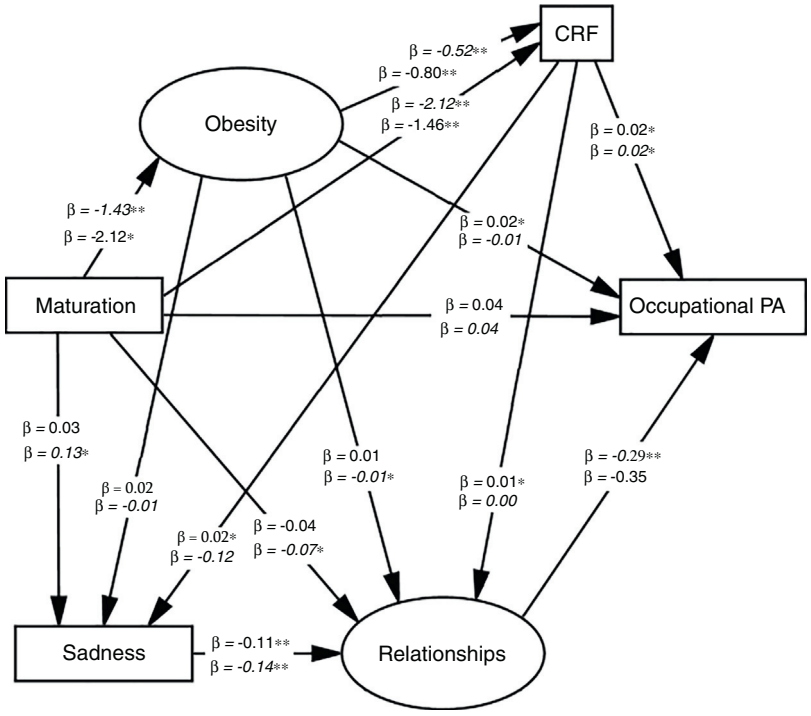

Figure 2 Final model for the association between biological and behavioral factors and occupational physical activity by sex. Data in italics refer to girls. Fit parameters for boys: $\chi^2 = 27.49$ ($p = 0.051$); $\chi^2/df = 1.62$; RMSEA = 0.03; CFI = 0.99; TLI = 0.97. Fit parameters for girls: $\chi^2 = 37.09$ ($p = 0.003$); $\chi^2/df = 2.18$; RMSEA = 0.04; CFI = 0.99; TLI = 0.97. *$p < 0.05$; **$p < 0.001$. χ^2, Chi-squared; df, degrees of freedom; RMSEA, root mean square of approximation; CFI, comparative fit index; TLI, Tucker–Lewis index.

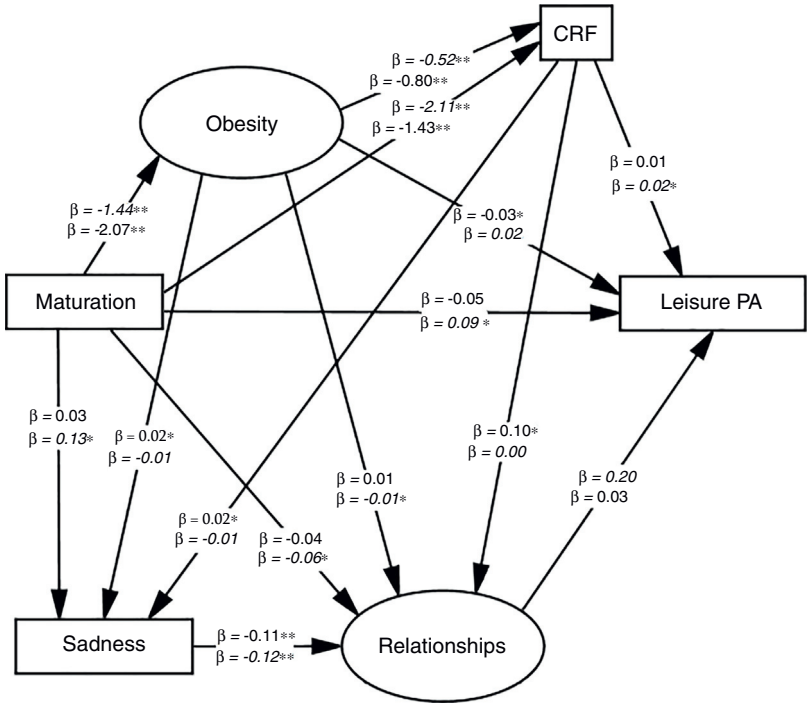

Figure 3 Final model for the association between biological and behavioral factors and leisure physical activity by sex. Data in italics refer to girls. Fit parameters for boys: $\chi^2 = 29.12$ ($p = 0.033$); $\chi^2/df = 1.71$; RMSEA = 0.03; CFI = 0.99; TLI = 0.97. Fit parameters for girls: $\chi^2 = 21.74$ ($p = 0.195$); $\chi^2/df = 1.28$; RMSEA = 0.02; CFI = 0.99; TLI = 0.99. *$p < 0.05$; **$p < 0.001$. χ^2, Chi-squared; df, degrees of freedom; RMSEA, root mean square of approximation; CFI, comparative fit index; TLI, Tucker–Lewis index.

have higher cardiorespiratory fitness. These findings can be related to the adiposity measures used in the present study, which do not have sensibility to assess body compartments. Thus, the improvement in total body size (including muscle mass) in boys who matured early probably was classified as body fat. Nonetheless, both adiposity and cardiorespiratory fitness have been correlated to physical activity in youth.[8] However, it is not clear the direction of these associations, and further longitudinal studies are needed. In the present study, the authors highlight the importance between adiposity and cardiorespiratory fitness as intermediate of maturity and physical activity.

With regard to psychological/social pathways, the effects were mainly observed in girls and for the sport domain. Early matured girls reported more sadness feelings, which were inversely related with social relationship satisfaction, which in turn appears to predict lower sport practice. In direct contrast, advanced girls reported higher satisfaction with social relationship. The authors speculate that, although the first path (sadness > social relationship > sport practice) appears to be stronger, a possible interaction with adiposity (greater adiposity, worst social relationship) could explain this result. Thus, apart from pointing out some other important psychological factors, as body image, self-competence, self-worth, and peer acceptance, which have been studied as mediator or moderator of the relation between maturity and physical activity,[7,12,14,15] the authors emphasize the interaction between biological, psychological, and social factors in the explanation of health behavior. In boys, for example, no direct psychological/social paths were found; however, cardiorespiratory fitness was positively related to satisfaction with social relationships. The interaction between them could promote higher levels of sport and occupational physical activity, indicating, in agreement with previous studies,[11] a clearer stronger relationship between biological maturation among girls than boys due to social contexts.

The current study had limitations that must be pointed out. The cross-sectional design does not allow temporality between variables; however, our theoretical model was based on longitudinal evidence.[27] Self-reported physical activity may have caused some bias; however, the questionnaire adopted has been validated for Brazilian adolescents[28] and showed good reproducibility in the present sample (ICC = 0.73). The validation of age at peak height velocity, given by the maturity-offset protocol used in the current study was recently criticized based on longitudinal data in both sexes.[29] The sample of the present study comprised adolescents aged 10–17, and the two aforementioned studies with Polish school children evidenced a correlation between chronological age and the estimates of age at peak height velocity derived from the maturity-offset protocol. Moreover, considering the wide range of chronological age (10–17 years), even with the statistical adjustments, it is possible that this heterogeneity could impact on the behaviors (e.g., physical activity) and biological variables (e.g., cardiorespiratory fitness and adiposity).[4,9] The errors of estimation were consistently narrower on years around actual peak height velocity calculated from respective the longitudinal data. Among the strengths of the present study, the authors highlight the use of an objective method to estimate somatic maturation,[20] which represents just one domain of biological maturation but has moderate association with sexual, bone, and cognitive maturation.[9] Moreover, this is the first study conducted with representative sample of adolescents from a Brazilian city, with aspects of a developing country, and analyzed by structural equation model, which allowed an integrated view on multivariate associations.

The biocultural model can help multi-component physical activity interventions targeting specific groups. It has been shown that early maturing adolescents are more likely to pursue unhealthy behaviors[30] and to be at cardiovascular risk.[10] Based on the current findings, focusing on biological, psychological, and social mediators should optimize physical activity promotion strategies. Specific actions for advanced in maturing adolescents that prevent obesity and poor cardiorespiratory fitness through a pleasant environment that stimulates positive feelings and social interactions could be a good option. In this sense, it is expected that biological improvements provide psychological/social benefits and vice versa.

Finally, it can be concluded that somatic maturation is directly associated with sport practice and leisure time physical activity among girls. Regarding the association between somatic maturation in predicting leisure time physical activity among both sexes, sports practice and occupational physical activity among boys, biological (adiposity and cardiorespiratory fitness), psychological (sadness feelings), and social (satisfaction with relationships) variables mediated the association. Thus, the study presents evidence of the validity of a biocultural model for health behavior approach during adolescence.

Funding

Brazilian Council of Scientific and Technological Development (CNPq: 483867/2009-8).

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgments

The authors would like to thank the administrators of the schools in which the study was conducted, for allowing the researchers to conduct observations, and the young individuals who took part in this investigation. The authors would also like to thank Décio Barbosa, Alessandra Okino, Jair Oliveira, Danielle Venturini, Crisieli Tomeleri, Mariana Carnelossi, and Sandra Kawaguti for their substantial contributions to the research, including assistance in data collection and entry. This study was funded by the National Council of Scientific and Technological Development (CNPq/Brazil–Process 483867/2009–8). ERVR, ESC, and RAF were supported by grants from CNPq/Brazil. DRS (sandwich doctorate scholarship – process 201022/2015–0) and AOW (scientific initiation) were also supported by CNPq.

References

1. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. Effect of physical inactivity on major non-communicable

diseases worldwide: an analysis of burden of disease and life expectancy. Lancet. 2012;380:219–29.
2. Howie EK, McVeigh JA, Smith AJ, Straker LM. Organized sport trajectories from childhood to adolescence and health associations. Med Sci Sports Exerc. 2016;48:1331–9.
3. Janssen X, Mann KD, Basterfield L, Parkinson KN, Pearce MS, Reilly JK, et al. Development of sedentary behavior across childhood and adolescence: longitudinal analysis of the Gateshead Millennium Study. Int J Behav Nutr Phys Act. 2016;13:88.
4. Rauner A, Jekauc D, Mess F, Schmidt S, Woll A. Tracking physical activity in different settings from late childhood to early adulthood in Germany: the MoMo longitudinal study. BMC Public Health. 2015;15:391.
5. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. Global physical activity levels: surveillance progress, pitfalls, and prospects. Lancet. 2012;380:247–57.
6. Pesquisa Nacional de Saúde do Escolar (PeNSE) 2015. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística (IBGE); 2016.
7. Cumming SP, Sherar LB, Pindus DM, Coelho-e-Silva MJ, Malina RM. A biocultural model of maturity-associated variance in adolescent physical activity. Int Rev Sport Exerc Psychol. 2012;5:23–43.
8. Silva DR, Fernandes RA, Ohara D, Collings PJ, Souza MF, Tomeleri CM, et al. Correlates of sports practice, occupational and leisure-time physical activity in Brazilian adolescents. Am J Hum Biol. 2016;28:112–7.
9. Malina RM, Bouchard C, Bar-Or O. Growth, maturation and physical activity. 2nd ed. Human Kinetics; 2004.
10. Werneck AO, Silva DR, Collings PJ, Fernandes RA, Ronque ER, Barbosa DS, et al. Biological maturation, central adiposity, and metabolic risk in adolescents: a mediation analysis. Child Obes. 2016;12:377–83.
11. Sherar LB, Cumming SP, Eisenmann JC, Baxter-Jones AD, Malina RM. Adolescent biological maturity and physical activity: biology meets behavior. Pediatr Exerc Sci. 2010;22:332–49.
12. Cumming SP, Standage M, Loney T, Gammon C, Neville H, Sherar LB, et al. The mediating role of physical self-concept on relations between biological maturity status and physical activity in adolescent females. J Adolesc. 2011;34:465–73.
13. Smart JE, Cumming SP, Sherar LB, Standage M, Neville H, Malina RM. Maturity associated variance in physical activity and health-related quality of life in adolescent females: a mediated effects model. J Phys Act Health. 2012;9:86–95.
14. Jackson L, Cumming SP, Drenowatz C, Standage M, Sherar L, Malina RM. Biological maturation and physical activity in adolescent British females: the roles of physical self-concept and perceived parental support. Psychol Sport Exerc. 2013;14:447–54.
15. Lee EY, An K, Jeon JY, Rodgers WM, Harber VJ, Spence JC. Biological maturation and physical activity in South Korean adolescent girls. Med Sci Sports Exerc. 2016;48:2454–61.
16. Cumming SP, Sherar LB, Gammon C, Standage M, Malina RM. Physical activity and physical self-concept in adolescence: a comparison of girls at the extremes of the biological maturation continuum. J Res Adolesc. 2012;22:746–57.
17. Brazilian Institute of Geography and Statistics (IBGE). Gross domestic product of municipalities; 2013. Available from: http://www.ibge.gov.br/cidadesat/xtras/perfil.php?codmun=411370&search=parana [cited 05.07.13].
18. Baecke JA, Burema J, Frijters JE. A short questionnaire for the measurement of habitual physical-activity in epidemiological-studies. Am J Clin Nutr. 1982;36:936–42.
19. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med. 2016;15:155–63.
20. Mirwald RL, Baxter-Jones AD, Bailey DA, Beunen GP. An assessment of maturity from anthropometric measurements. Med Sci Sports Exerc. 2002;34:689–94.
21. Harrison G, Buskirk E, Carter L, Johnston F, Lohman T, Pollock M. Skinfold thicknesses and measurement technique. In: Lohman T, Roche A, Martorell R, editors. Anthropometric standardization reference manual. Champaign: Human Kinetics Books; 1988.
22. Leger LA, Lambert J. A maximal multistage 20-m shuttle run test to predict VO_2 max. Eur J Appl Physiol Occup Physiol. 1982;49:1–12.
23. Leger LA, Mercier D, Gadoury C, Lambert J. The multistage 20 metre shuttle run test for aerobic fitness. J Sports Sci. 1988;6:93–101.
24. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW, et al. Correlates of physical activity: why are some people physically active and others not? Lancet. 2012;380:258–71.
25. Good DJ, Li M, Deater-Deckard K. A genetic basis for motivated exercise. Exerc Sport Sci Rev. 2015;43:231–7.
26. Pindus DM, Cumming SP, Sherar LB, Gammon C, Coelho e Silva M, Malina RM. Maturity-associated variation in physical activity and health-related quality of life in British adolescent girls: moderating effects of peer acceptance. Int J Behav Med. 2014;21:757–66.
27. MacKinnon DP, Fairchild AJ, Fritz MS. Mediation analysis. Annu Rev Psychol. 2007;58:593–614.
28. Guedes DP, Lopes CC, Guedes JE, Stanganelli LC. Reprodutibilidade e validade do questionário Baecke para avaliação da atividade física habitual em adolescentes. Rev Port Cien Desp. 2006;6:265–74.
29. Malina RM, Choh AC, Czerwinski SA, Chumlea WC. Validation of maturity offset in the Fels Longitudinal Study. Pediatr Exerc Sci. 2016;28:439–55.
30. Simon AE, Wardle J, Jarvis MJ, Steggles N, Cartwright M. Examining the relationship between pubertal stage, adolescent health behaviours and stress. Psychol Med. 2003;33:1369–79.