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Human Kinetics
REVIEW

Longitudinal Association Between Physical Activity and Body Fat During Adolescence: A Systematic Review

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***Background*:** Physical activity (PA) practice has been inversely associated to body fat (BF) and recommended as a way to reduce and prevent obesity. The objective of this study was to conduct a systematic review on the association of PA and BF in adolescence. ***Methods*:** The review includes 18 longitudinal studies found in the PubMed database, comprising papers published from January 1990 to July 2014. Studies assessing BF only through body mass index were excluded. ***Results*:** Among the outcomes analyzed, waist circumference, skinfolds, and absolute and relative fat mass measurement were identified. Questionnaires were the more predominant way to evaluate PA. Most studies showed that PA promotes a protective effect against a higher BF gain. ***Conclusion*:** It was concluded that PA has a protective effect against BF with differences between the genders and according to the BF marker or measurement assessed; higher intensity PA leads to a greater effect against BF gain in both genders; and the maintenance or increase of PA level on BF observed through analysis of change in PA level yielded more consistent findings in the relation between PA and BF.

***Keywords*:** adolescents, motor activity, longitudinal studies

Overweight in the world population has quickly expanded over the last 3 decades.[1,2] When overweight onsets in childhood and adolescence, it tends to remain throughout adult life[3,4] and increases the risk of development of chronic degenerative diseases and early death.[5–8] Data from surveys carried out in European and American countries[9–11] point to an important evolution of the percentage of overweight and obese adolescents. In countries such as Brazil and the United States, for instance, which have different cultures and economies, obesity prevalence in adolescents between 10 and 19 years of age increased from 1.3% to 5% and from 11.0% to 18.0%, respectively, between the late 1980s and 2008.[9,10]

Adolescence is characterized by a dynamic development marked by quick physical changes, among others, such as body size, shape, and composition.[12] In this context, with the purpose of obtaining information to support the planning of actions to control the increase in the prevalence and incidence of obesity among adolescents, it is important to follow the development of body composition in this population, especially in relation to its major components: fat mass (FM), lean mass (LM), and bone mineral density (BMD), as well as the factors that are related to them. Several factors are known to affect the development of the main components of body composition (bone, muscle, and fat), such as hereditary, social, environmental, cognitive, and lifestyle factors. Among the lifestyles, physical activity (PA) has been strongly associated with body composition.[2,13]

Many studies have pointed out that PA practice has a protective effect against weight gain and BF.[14–16] Given this fact, PA practice has been a common and important recommendation to minimize negative effects of BF on health and to help in maintaining weight.[17–19] Nevertheless, even with a vast literature, there is no consensus regarding the longitudinal relation between PA and BF.[20,21] Among many questions about how PA could affect BF is the type of PA (leisure, commuting, household, and occupational) and its frequency, duration, and intensity in the various combinations.[22,23]

Several studies with adolescents using different designs have been carried out aiming to clarify the effects of PA practice on body composition and, particularly, BF.[24–28] Cross-sectional studies report that more active adolescents have lower BF levels.[14,25,29–32] Experimental studies have similar findings, but they have mostly been carried out with obese adolescents who were assessed over a short period of time (weeks and/or months).[27,33,34] Many of the longitudinal cohort studies with this age group have used BMI as an outcome to classify the nutritional status and pointed out that those who are more active have lower BMI values.[35–37] However, using BMI as a body composition indicator may lead to severe classification errors because subjects considered overweight or obese may have large bone or muscle mass.[38,39]

Body composition can be accessed through several measurements and methods. Anthropometric measure, such as BMI, is the measure more widely used to assess body composition. However, there is the possibility of erroneously classifying subjects' BF amount.[38–40] Some anthropometric measurements, as is the case of skinfolds (SF) and waist circumference (WC), are easily measured, less expensive, and could provide reasonable information about the amount of BF. Further, SF may be used to provide the FM% estimated through of equations.[41] Measures of the FM and LM provide more accurate information about absolute and relative amounts of BF. Nevertheless, their methods of measure are very expensive and still little used in studies on large populations given their high costs and logistic difficulties.[41,42]

The current study consists of a systematic review aiming to compile and examine findings from observational longitudinal studies which have investigated the relationship between PA practice and its effect on BF during adolescence. The article's hypothesis is that maintained high levels of PA practice are inversely related to BF, especially when more accurate measures of BF are used.

Methods

This systematic literature review was carried out on the PubMed/Medline electronic database. The electronic search used 4 types of combinations. The Boolean operator "OR" was used between the

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descriptors of each group and the operator "AND," between the groups. In the first group, the following descriptors referred to the outcome of interest: obese, obesity, fatness, adiposity, body fat, body composition, body weight, overweight, body mass index, fat mass, free fat mass, and lean mass. The second group of descriptors referred to the exposure investigated: physical activity, inactivity, sports, exercise, and motor activity. In the third group, the following descriptors referred to the population of interest: adolescent, adolescence, young, youth, teenager, teenage, children, childhood, and lifespan. The fourth group of descriptors referred to the type of study: longitudinal, cohort, prospective, panel, follow-up, long term, and trajectory.

The following items were considered to meet the inclusion criteria of this review: a) observational studies with cohort design and longitudinal analyses published between January 1990 and July 2014; b) articles in which the exposure (PA practice) and outcome (BF) were collected during adolescence; and c) articles assessing BF by measuring total fat aspects such as LM and FM% or regional fat indicators such as SF and WC. In studies that followed the subjects from childhood to adulthood, only the adolescence period was considered (10 to 19 years old). This age period was selected as it is the time when the highest changes in terms of body composition during adolescence take place.[12,43] The following exclusion criteria were considered in this review: a) assessing BF only through BMI; b) cross-sectional, experimental, or case-control design; c) considering only PA performed in physical education class; and d) review papers, thesis and dissertations, and nonpublished papers.

The article search and selection processes were carried out by the first author. However, when there was doubt about whether the papers met the eligibility criteria, the other authors were consulted about including or excluding such papers. In 3 pairs of studies the same sample was used providing information about the relationship between PA and BF (Bélanger and Barnett,[51,52] Hallal and Martinez-Gomez,[61,62] Stevens and Cohen[54,59]). We chose to keep these studies as they used different outcomes, types of analysis, or ways of measuring BF. The process of identification, screening, eligibility, and inclusion of articles are described in Figure 1. This article was written based on the guidelines of the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) Statement.[44]

Results

The description of the studies included in this review is shown in Table 1.All studies were published after 2005. Most studies (N = 16) were carried out in high-income countries, 6 of which were in Europe[45–50] and 10 of which were in North America,[51–60] including 6 in the United States.[54–57,59,60] Only 2 studies were carried out in an average- and low-income country (Brazil) in South America.[61,62] Sample size greatly varied with a minimum number of 201 and maximum of 4150 subjects (mean = 1075 and median = 674). Five studies assessed only female adolescents. At baseline, the studies included subjects between 8 and 14 years old (mean = 11.2 years, median = 12 years). At endline, ages assessed ranged between 12 and 20 years old (mean = 16.5 years, median = 17 years). The follow-up periods between baseline and endline ranged from 2 to 9 years (mean and median = 5.0 years). A predominance of questionnaires to measure PA practice was observed (N = 11).[46–48,50–52,55,56,58,61,62] Objective PA measurement using accelerometers was identified in 8 studies.[45,49,53,54,57,59–61] In 12 studies, the researchers measured total PA[49,51–61] while in 4, only leisure PA was considered.[46–48,50] In 2 studies active commuting was considered.[45,62] Other characteristics and main results of the 18 studies included in this review are summarized in Table 2 according to the type of outcome assessment.

The relation between PA practice and BF measured through anthropometric methods was identified in 10 studies.[45–48,52,53,56,60–62] Among the BF markers used, WC appeared in 6 studies[45–47,52,53,62] and SF in 8.[45–48,52,56,60,61] In the study by Stevens et al,[59] the researchers measured triceps SF and the nutritional state (ie, BMI) to predict the percentage of total BF through an equation. Further, measures of FM and FM% were also the method used to evaluate BF. Five studies measured FM, 4 by using DXA, which provides absolute or relative FM and LM.[49,57,58,62] One study evaluated FM through isotope dilution (deuterium),[61] which assesses total body water and enables estimating FM from the difference between LM and total weight. In 6, the FM% was the measurement of BF, with 3 studies using electric bioimpedance,[47,54,55] which estimates total body water and predicts %BF through gender- and age group–specific equations, 2 equations predictive[51,59] and 1 DXA.[50]

Three forms of longitudinal analysis of the relation between PA and BF were identified among the studies: 1) effect of PA measured at baseline on BF at endline (predictive analyses) was used in 8 studies;[46–49,53,54,60,61] 2) change in PA level during adolescence and its association with BF measured at endline was assessed in 11 studies;[45,47,50–52,55–59,62] and 3) relation between change in PA level and change in BF was used in 1 study.[49]

Among the predictive studies, 5 assessed BF through SF,[46–48,60,61] 3 measured the WC,[46,47,53] 2 FM,[49,61] and 2 FM%.[47,54] In general, they did not find any association between PA and SF or WC in both sexes. However, Carson et al[53] found that boys with higher levels of vigorous PA had lower measures of WC. Unlike what was expected, Freitas et al[46] and Kettaneh et al[47] found that a high level of PA predicts a higher average skinfold sum (SFS) in females. Yet, Kettaneh et al[47] found the same results for WC. The predictive analysis of the relation between PA and BF measured by more precise methods was assessed in 4 studies. Two of them analyzed the effects of PA on FM[49,61] and 2 on FM%.[47,54] In the study by Cohen et al,[54] an inverse relationship between vigorous PA practiced at 13 years old and %BF at 18 years old was observed in female adolescents. The same results were found by Riddoch et al[49] for male and female adolescents in checking the effects of total PA and moderate-to-vigorous physical activity (MVPA) at 12 years old on FM at 14 years old, with a greater magnitude of the effect for MVPA. The only study on the relation between PA and %BF presented opposite results: girls who were more active in leisure at 13 years old had a higher average of %BF at 15 years old.[47]

Change in PA levels between baseline and endline and its effect on BF was assessed in 4 studies by SF,[45,47,52,56] in 4 by WC,[45,47,52,62] in 4 studies by FM,[49,57,58,62] and in 5 studies using FM%.[47,50,51,55,59] Even using a more robust analysis of the BF markers SF and WC still presents lower association with PA. However, some interesting results were found. Martinez-Gomez et al,[62] who studied the relationship between WC and the change in active commuting from 11 to 18 years old in boys and girls, found inverse association only for boys. Also considering the change in PA level, but only for vigorous PA, Kettaneh et al[47] found that boys who increased their levels of vigorous PA had the lowest mean SFS compared with those whose PA levels decreased. The study by Bélanger et al,[52] which assessed adolescents of both genders, reported that girls with the greatest variation in the number of weekly MVPA sessions between 12 and 17 years old had the lowest mean subscapular and triceps SF and WC at 17 years old. In addition, girls who maintained a high leisure MVPA level had the lowest mean WC when compared with those whose PA levels decreased. Among the studies using FM and FM% as measure of BF, the results were more consistent, especially for FM in boys. All studies found inverse association between

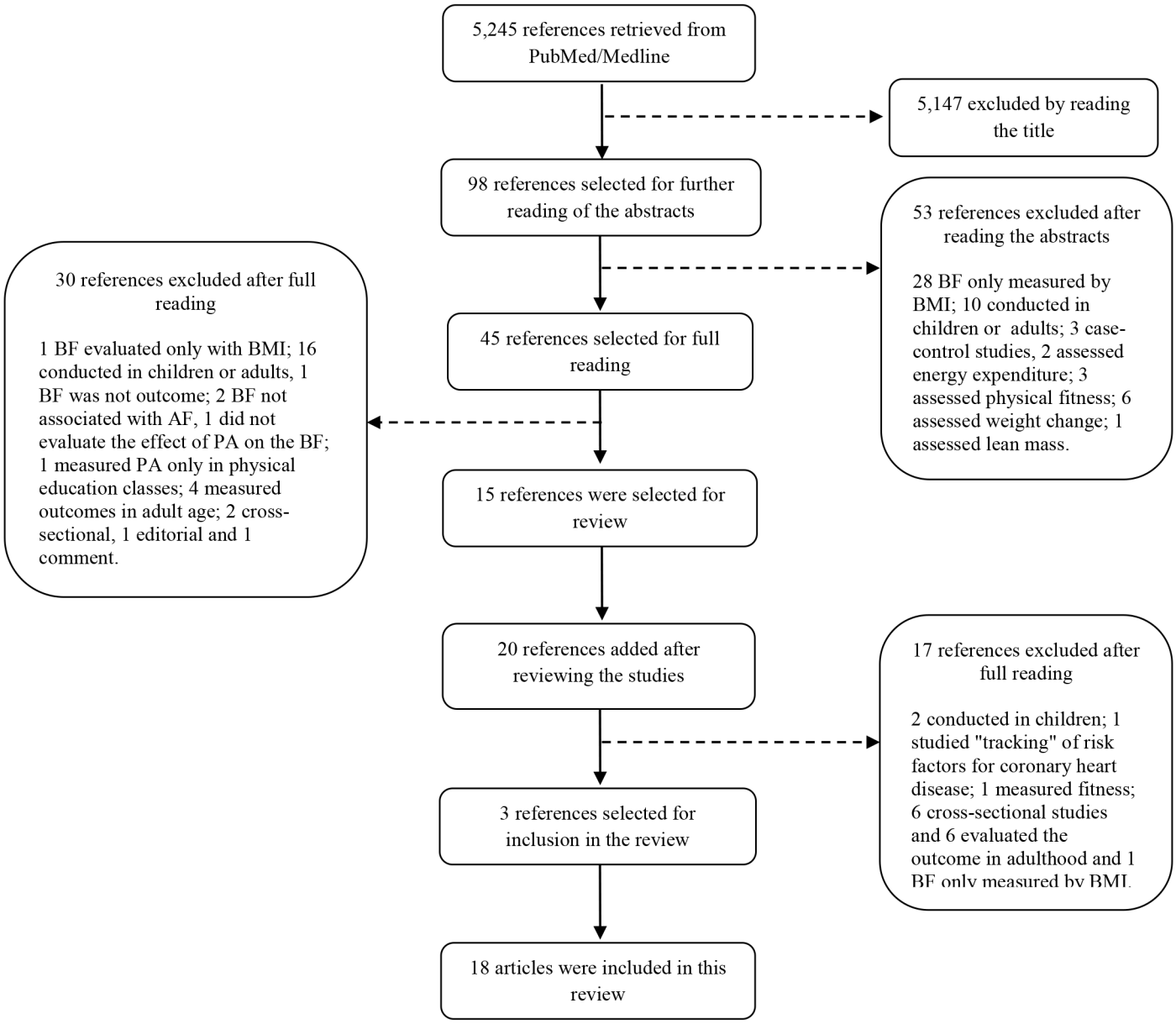

Figure 1 — Flow-chart for the selection process.

FM[49,57,58,62] and PA and FM% in girls, who had the PA practice inversely related to FM% in all 5 studies.[47,50,51,55,59]

Analysis of the relationship between change in PA level and change in BF was identified for only 1 study, which demonstrated an inverse association between increase in total PA (100 more counts per minute) and in MVPA (15 minutes more per day) from 12 to 14 years old and the percentage of FM change over the same period in adolescents of both genders. The magnitude of the effect found for MVPA was greater than the 1 of total PA.[49]

Discussion

PA practice in adolescence promotes some protective effect against a higher BF gain. This effect was related to the different BF development and distribution in girls and boys during this period of their lives. PA practice in adolescence may have a protective effect regarding the maintenance, slowing down, or reduction in BF, but the response of BF markers and of BF itself are conditioned to how they develop and may be modified by PA practice. When BF was assessed by more precise measurements, the total BF, such as FM or FM%, was inversely associated with PA in boys and FM% in girls. Further, among the studies included in this review, it was possible to identify that PA practice with heavier intensity had a greater inverse effect on BF.[45,47,49–51,53–59,62] Also, the longitudinal PA practice analysis model (change or prediction) presented an influence in the results, including most studies that used the prediction model and did not find any association or found positive association between PA and BF.[46–48,61]

The physical activity practice has been recommended for maintenance or reduction of the weight and BF.[63,64] However, many questions remain about which amount or intensity is more adequate to promote effect on weight and BF.[20,21] Some studies suggest that a large amount of PA is capable to promote stability

Table 1 Description of Studies Included in This Review

Variable	Number of studies
Year of study	
2005–2009	7
2010–July 2014	11
Continent	
North America	10
South America	2
Europe	6
Sample size	
200–1000	12
>1000	6
Sex	
Male and female	13
Female	5
Follow-up (years)	
1–3	7
4–6	4
7–10	7
Body fat (BF) assessment method*	
Fat mass percentage†	6
Fat mass	5
Waist circumference	6
Skinfold	8
Fat mass or fat mass percentage assessment method§	
Duel-energy X-ray absorptiometry (DEXA)	5
Bioimpedance	3
Equation	2
Dilution of Deuterium	1
Physical activity (PA) assessment method	
Questionnaire	10
Accelerometer	7
Questionnaire and accelerometer	1
Negative association between PA and BF (adjusted and $P < .05$)	
Only males	3
Only females**	7
Both	4
Association not found	4

† One study converted fat mass percentage on FMI (Fulton et al 2009); * In 4 studies, the body fat was evaluated in more than 1 way; § Only studies that measured FM or FM%; ** Five studies (Kimm et al 2005; Stevens et al 2007; Völgyi et al 2011; White et al 2012 and Cohen et al 2014) analyzed only girls.

or decrease in weight and BF.[27,65] On the other hand, researchers found that PA in high intensity is more important to maintain or reduce weight and BF.[25,31,66–68] In this review, the studies which considered MVPA[45,49,50,55–59,62] or vigorous PA[47,51,53,54] show results that PA at high intensity is more effective to maintain or decrease the BF during adolescence. The main reason for this might be the fact that, in general, PA practice in higher intensity promotes larger energy costs and increases the amount of lean mass, rising the energy expenditure during and after the PA practice.[20,69–73]

The differences verified in the relationship between PA and BF among adolescents is strongly connected to the specific development of each gender. The main body changes characteristic of this period is the increase in body weight. However, boys gain bigger amounts of LM while girls have a more marked gain in FM.[12,74,75] Thus, the effect of PA on BF might be affected by this relationship. As an example of this situation, we present the relationship between PA and FM%. For being a relative measure of the FM—relation between total body mass and FM—changes in LM might result in the decrease of the FM%, even without modifications in the FM component.[39,76] This might be observed especially in females, whom might gain a greater amount of LM through PA practice, especially of vigorous intensity. As a result, it was possible to observe in this review that PA and FM% showed an inverse association mainly among females.[50] Another main characteristic of the body development during adolescence that presented strong sexual dimorphism was the higher gain of LM by boys.[12] Once they naturally gained a greater amount of LM and generally spent more time with PA of vigorous intensity,[25,31,66] we hoped that the development of BF was slower. This relationship may be clearly observed on studies included in this review, as among those that verify the association between PA and FM most found an inverse association for boys, especially when the maintenance of the PA practice of higher intensity was considered.[49,57,58,62]

Similarly to LM and FM, SF also presents development related to sex. Among boys, the natural process of the development during this period was the maintenance or decrease of SF thickness while in girls there was a constant increase of thickness.[77–80] Thus, we believe that the effect of PA practice on SF was more easily observed in girls, because in boys the decrease in SF was part of the growth process. In this review, among the 8 studies that verified the effects of PA on SF, only 1 found an inverse relationship for boys. For girls, it seems that this relationship was not well defined, as many found inverse associations[52,56,60] and others direct associations[46,47] between PA and SF.

Studies which assessed the change in PA level during adolescence and considered the relationship between the PA trajectory and BF have more and better controlled information regarding the variation in PA over time.[81] In this review, most studies that developed this type of analysis found an inverse association between PA and BF for at least boys and/or girls.[47,50–52,55–59,62] On the other hand, when PA was analyzed as a predictor, most did not find an inverse association with BF[46,48,61] and, unlike what was expected, 2 studies found a positive relation between PA and BF for females.[46,47] The likely explanation is the fact that this method did not into take into account a series of events that happen in the period between the measure of exposure and outcome which may affect this relationship[81] (ie, one individual who was identified as active in baseline might be inactive in endline and conversely), especially in studies with longer intervals between baseline and endline points. Further, the adaptation and maintenance of the effects of PA practice on weight and BF occurs on a long term. Thus, the suspension in PA practice results in the loss of its benefits.[82]

Taking into account only the relation between PA practice and BF measured by methods that represent the total BF, absolute or relative, we verified that the associations were more consistent than those found in studies that measured BF with anthropometric methods, such as SF and WC, particularly between those that assessed the change in PA level. This was observed in spite of the heterogeneous methodologies regarding the sampling process, exposures, analysis model, and ages, which impairs comparisons and generalization of the relations investigated. Regarding PA measurement, although the accelerometer provides a more precise measure of total PA and its intensities, it was found that the most important aspect observed in the associations was the qualification of PA intensity, independent

Table 2 Summary of the Longitudinal Studies With Analysis of the Association Between Physical Activity and Body Fat During Adolescence as Assessed Outcomes

Author(s) / year	Sample	Age(s) baseline (years)	Age(s) follow-up (years)	Type of long-term analysis	Exposure / instrument	Outcome / instrument	Main results	Effect magnitude	Comparison group	Adjustment
Kimm, et al 2005	2287 females	9 and 10	18 and 19	Change in PA	Total PA Questionnaire (HAQ)	SSF	The differences between the SSF in active and inactive were 16.04 mm and 13.54 mm for white and black, respectively. A reduction of 10 METs/ week of PA was associated with an annual increase in SSF of 0.62 mm and 0.63 mm for girls black and white, respectively.	Females black ΔSSF year 1 → –7.32mm $P < 0.001$ ΔSSF year 10 → –16.04mm $P < 0.0001$ Females white ΔSSF year 1 → –5.35mm $P < 0.0001$ ΔSSF year 10 → –13.54mm $P < 0.0001$	Active X Inactive Active (20 or more MET-times per week). Inactive (10 or fewer MET-times per week). Mean difference between being active or inactive in each period.	PA score and energy intake in year one, age of menarche, childbirth, year of study, smoking and change in PA score and energy intake.
Kettaneh et al 2005	436 All (222 males and 214 females)	13	15	Predictive PA at 13 years → SSF at 15 years	LTPA Questionnaire (MAQ)	SSF	For girls, being in the group with the highest level of moderate activity at baseline predicted the highest SSF from baseline to follow-up.	♀—moderate PA Mean (CI) → $P = 0.01$ Low → 45.6 (43.5; 47.9) High → 49.7 (47.5; 52.1) ♂—no association	Low or high level of activity according to the median value of the corresponding activity within their sex and age strata.	Tanner stage and age, The WC has also been adjusted for height at baseline.
				Change in PA			In boys, the SSF was higher at follow-up in those who had decreased their level of vigorous PA and lower in those who had increased it.	♂—Vigorous PA mean (CI) → $P = 0.008$ Decreased → 35.5 (34.5; 38.8) Increased → 31.1 (28,9;33,4) ♀—no association	Four groups according to change in PA on baseline and follow-up: decreased, maintained low, maintained high and increased.	
Kvaavik et al 2009	1016 males and females	13	15	Predictive PA at 12 years → SF at 15 years	LTPA Questionnaire	SF (TR)	LTPA was not associated with SF triceps in life course in males e females.	♂—no association ♀—no association	PA practice more than 2 times a week.	Age and socioeconomic status.
Bélanger et al 2011	756 All (369 males and 387 females)	12	17	Change in PA	Total PA Questionnaire (7-d PA recall)	SF (TR)	Higher score of fluctuations in PA was associated with smaller measures of SF subscapular and triceps only in females.	♂—no association ♀—β (CI) → –0.2 (–0.38; –0.05) ♂—no association	More × Less PA score fluctuation.	WC, SF triceps and subscapular, average number of MVPA sessions per week at baseline, diet, family status, number of siblings, mother's education.
						SF (SB)		♀— β (CI) → –0.4 (–0.56; –0.26)		

(continued)

Table 2 *(continued)*

Author(s) / year	Sample	Age(s) baseline (years)	Age(s) follow-up (years)	Type of long-term analysis	Exposure / instrument	Outcome / instrument	Main results	Effect magnitude	Comparison group	Adjustment
Andersen et al 2011	334 All (147 males and 187 females)	9	15	Change in PA	Active commuting (cycling) to school Accelerometry	SSF	Active commuting (cycling) to school at age 12 years was not associated with SSF at age 14 years in boys and girls.	Cycling to school at age 12 years and at age 14 years and SSF at age 14 years → Mean (SD) Never → 45.9 (23.7) Only in 1997 → 43.5 (24.1) Only in 2003 → 45.3 (20.9) Always → 43.4 (18.2)	Change in way of commuting to school between 12 to 14 years Never Only in 1997 Only in 2003 Always	Baseline values of risk factors, time of baseline measurement and sex.
Freitas et al 2012	670 All (226 males and 434 females)	12	19	Predictive PA at 12 years → SSF at 19 years	LTPA Questionnaire (Baecke)	SSF	In females, the "Sport index" to 12 years was a predictor of positive variation of 3% in SSF at 19 years.	♂—no association ♀—β = 12.0—R^2 0.03	PA index (range 1–5)	Physical characteristics (height, body mass, BMI, WC and SSF), physical fitness variables, PA and biological maturity.
White et al 2012	1148 Females (538 black and 610 white)	12	14	Predictive PA at 12 years → SSF at 14 years	Total PA Accelerometry	SSF	In the fully adjusted models, the odds ratios for obesity (≥90th percentile for SSF) between the top and the bottom quartiles accelerometer (counts/day) were inversely associated in white girls (P = .03 for trend).	White girls → OR (95%CI) Bottom → reference Second → 0.47 (0.15; 1.45) Third → 0.21 (0.06; 0.71) Top → 0.15 (0.04; 0.63) Black girls → OR (95%CI) Bottom → reference Second → 0.90 (0.37; 2.19) Third → 0.72 (0.27; 1.89) Top → 0.85 (0.32; 2.26)	Quartiles of counts per day. Bottom is the reference category.	BMI, BF%, height, height square, highest level of parental education, total annual household income, hour of TV for week, MET's PA for week, total caloric intake for week at age 12 years and pubertal stage at age 12 and 14 years.
Hallal et al 2012	511 males and females	11	13	Predictive PA at 11 years → SSF at 13 years	Total PA Accelerometry	SSF	MVPA at 11.3 years and SSF at 14.7 years were not associated.	♂—no association ♀—no association	Inactive × Active (<300 min/week spent in MVPA). MVPA >2000 counts/day.	Socioeconomic status, mother's BMI before pregnancy, maternal smoking during pregnancy, birth order, maternal education, and pubertal stage, WC and SSF at baseline.

(continued)

Table 2 *(continued)*

Author(s) / year	Sample	Age(s) baseline (years)	Age(s) follow-up (years)	Type of long-term analysis	Exposure / instrument	Outcome / instrument	Main results	Effect magnitude	Comparison group	Adjustment
Kettaneh et al 2005	436 All (222 males and 214 females)	13	15	Predictive PA at 13 years → WC at 15 years	LTPA Questionnaire (MAQ)	WC	Girls with the highest level of moderate activity at baseline had the highest WC on follow-up.	♀—Moderate LTPA mean (CI) → $P = 0.03$ Low → 65.8 (65.1; 66.5) High → 66.8 (66.2; 67.5) ♂—no association	Low or high level of activity according to the median value of the corresponding activity within their sex and age strata.	Tanner stage and age, The WC has also been adjusted for height at baseline.
				Change in PA			Girls who maintained the high level of LTPA had lower mean of WC, compared with those that decreased LTPA level.	♀—LTPA mean (CI) → $P = 0.03$ Decreased → 67.6 (66.7; 68.7) Maintained high → 65.6 (64.7; 66.5) ♂—no association	Four groups according to change in PA on baseline and follow-up: decreased, maintained low, maintained high and increased.	
Bélanger et al 2011	756 All (369 males and 387 females)	12	17	Change in PA	Total PA Questionnaire (7-d PA recall)	WC	Higher score of fluctuations in PA was associated with smaller measures of CC only in females.	♂—no association ♀—β (CI) → –0.54 (–0.91; –0.17)	More × Less PA score fluctuation.	WC, SF triceps and subscapular, average number of MVPA sessions per week at baseline, diet, family status, number of siblings, mother's education.
Andersen et al 2011	334 All (147 males and 187 females)	9	15	Change in PA	Active commuting (cycling) to school Accelerometry	WC	Active commuting (cycling) to school at age 12 years was not associated with WC at age 14 years in boys and girls.	Cycling to school at age 12 years and at age 14 years and WC at age 14 years → Mean (SD) Never → 76.1 (9.5) Only in 1997 → 73.9 (8.4) Only in 2003 → 74.1 (7.0) Always → 73.1 (6.2)	Change in way of commuting to school between 12 to 14 years Never Only in 1997 Only in 2003 Always	Baseline values of risk factors, time of baseline measurement and sex.
Freitas et al 2012	670 All (226 males and 434 females)	12	19	Predictive PA at 12 years → WC at 19 years	LTPA Questionnaire (Baecke)	WC	LTPA was not associated with WC in boys and girls during adolescence.	♂—no association ♀—no association	PA index (range 1–5)	Physical characteristics (height, body mass, BMI, WC and SSF), physical fitness variables, PA and biological maturity.

(continued)

Table 2 *(continued)*

Author(s) / year	Sample	Age(s) baseline (years)	Age(s) follow-up (years)	Type of long-term analysis	Exposure / instrument	Outcome / instrument	Main results	Effect magnitude	Comparison group	Adjustment
Carson et al 2014	313 All (128 males and 187 females)	12	15	Predictive PA at 12 years → WC at 15 years	Total PA Accelerometry	WC	WC decrease dose-response in follow-up with increasing time spent in vigorous-intensity PA in boys (Q1 vs. Q4 = 79.0 vs. 72.6 cm).	Light-intensity PA ♂ and ♀ → no association Moderate-intensity PA ♂ and ♀ → no association Vigorous-intensity PA WC → β (CI) ♂ → –0.03 (–0.07; 0.01) ♀ → no association	Quartiles of PA in light, moderate and vigorous.intensities,	Age, sex and dietary intake.
Martinez-Gomez et al 2014	3649 All (1689 males and 1780 females)	11	18	Change in PA	Active commuting and LTPA Questionnaire	WC	Active commuting at 15 years was prospectively associated inversely with WC in boys. Active commuting accumulated at 11, 15, and 18 years was associated with WC in boys. Changes in tertiles of active commuting of the 11 to 18 years and 15 to 18 years were associated with WC only in boys.	Active commuting accumulated at 11, 15, and 18 years and WC at 18 years → mean (95%CI) ♂ → High vs. Low tertile: –2.09 (–3.24; –0.94) ♀ → no association Change in active commuting from 11 to18 years and WC at 18 years → ♂ mean (95%CI) Consistently high → –2.92 (–4.75; –1.10) ♀ → no association Change in active commuting from 15 to18 years and WC at 18 years → ♂ mean (95%CI) Consistently high → –3.68 (–5.50; –1.86) ♀ → no association	Active commuting Tertiles (low, medium, and high) and change in tertiles (consistently low, decreasing, consistently middle, increasing and consistently high). Low and consistently low are the reference groups.	Association between accumulated active commuting was adjusted for accumulated changes in leisure time and family income at 11, 15, and 18 years. Association between changes in active commuting was adjusted for accumulated changes in leisure time and family income from 11 to 18 years and 15 to 18 years.
Mundt et al 2006	208 All (105 males and 103 females)	10	19	Change in PA	Total PA Questionnaire (PAC-C/ PAC-A)	FM DXA	PA was negatively associated with FM between assets only in males,	♂—(mean ± SD) –0.547 (0.268) → $P < 0.05$ ♀—no association	PA score (range 1–5) 1—Low 5—High	Biological maturity and FFM.

(continued)

Table 2 *(continued)*

Author(s) / year	Sample	Age(s) baseline (years)	Age(s) follow-up (years)	Type of long-term analysis	Exposure / instrument	Outcome / instrument	Main results	Effect magnitude	Comparison group	Adjustment
Riddoch et al 2009	4150 All (1964 males and 2186 females)	12	14	Predictive PA at 12 years → FM at 14 years	Total PA Accelerometry	FM DXA	Total PA and MVPA at age 12 were inversely associated with the FM in boys and girls at age 14.	Total PA ♂—% change (CI) → –6.4 (–7.8; –4.9) ♀—% change (CI) → –4.0 (–5.5; –2.5)	For total PA (counts/min), change in FM is for additional activity of 100 counts/min,	Total PA, MVPA and FM at baseline.
								MVPA ♂—% change (CI) → –11.9 (–14.3; –9.5) ♀—% change (CI) → –9.8 (–12.8; –6.7)	For MVPA (min/day), change in FM is for additional activity of 15 min/day,	
				Change in PA and Change in FM 12 to 14 years			The changes in total level of PA and MVPA from 12 to 14 years were inversely associated with change in FM of boys and girls from 12 to 14 years.	Change in Total PA (12 to 14y) ♂—% change in FM (CI) → –1.3 (–2.0; –0.6) ♀—% change in FM (CI) → –1.3 (–1.9; –0.6)	For total PA (counts/min), change in FM is for additional activity of 100 counts/min.	
								Change in MVPA (12 to 14y) ♂—% change in FM (CI) → –2.4 (–3.6; –1.1) ♀—% change in FM (CI) → –2.3 (–3.5; –1.2)	For MVPA (min/day), change in FM is for additional activity of 15 min/day.	
Hallal et al 2012	511 males and females	11	13	Predictive PA at 11 years → FM at 13 years	Total PA Questionnaire	FM Deuterium	PA at 11.3 years and FM at 13.3 years were not associated.	♂—no association ♀—no association	Inactive × Active (<300 min/week)	Socioeconomic status, mother's BMI before pregnancy, maternal smoking during pregnancy, birth order, maternal education, and pubertal stage, WC and SSF at baseline.
Kwon et al 2013	554 All (277 males and 277 females)	8	15	Change in PA	Total PA Accelerometry	FM DXA	Growth model shows that moderate-to-vigorous PA was associated with 3.0% and 1.5% lower FM in boys and girls, respectively.	MVPA FM → β ±(SE) ♂ → 0.10 (0.02) → $P < 0.01$ ♀ → 0.05 (0.01) → $P < 0.01$	MVPA time level Low Medium High	Age, height and peak velocity height.

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Table 2 *(continued)*

Author(s) / year	Sample	Age(s) baseline (years)	Age(s) follow-up (years)	Type of long-term analysis	Exposure / instrument	Outcome / instrument	Main results	Effect magnitude	Comparison group	Adjustment
Martinez-Gomez et al 2014	3649 All (1689 males and 1780 females)	11	18	Change in PA	Active commuting and LTPA Questionnaire	Trunk FM DXA	Active commuting at 15 and 18 years was prospectively inversely associated with trunk fat mass in boys.	Active commuting accumulated at 11, 15, and 18 years and Trunk fat mass at 18 years → mean (95%CI) ♂ → High vs. Low tertile: –1.11 (–1.74; –0.48) ♀ → no association	Active commuting Tertiles (low, medium and high) and change in tertiles (consistently low, decreasing, consistently middle, increasing and consistently high).	Association between accumulated active commuting was adjusted for accumulated changes in leisure time and family income at 11, 15, and 18 years.
							Active commuting accumulated at 11, 15, and 18 years was associated with trunk fat mass in boys.	Change in active commuting from 11 to18 years and TFM at 18 years → ♂ mean (95%CI) Consistently high → –1.74 (–2.74; –0.75) ♀ → no association	Low and consistently low are the reference groups.	Association between changes in active commuting was adjusted for accumulated changes in leisure time and family income from 11 to 18 years and 15 to 18 years.
							Changes in tertiles of active commuting of the 11 to 18 years and 15 to 18 years were associated with trunk fat mass only in boys.	Change in active commuting from 15 to18 years and TFM at 18 years → ♂ mean (95%CI) Consistently high → –2.01 (–3.00; –1.02) ♀ → no association		
Kettaneh et al 2005	436 All (222 males and 214 females)	13	15	Predictive PA at 13 years → FM% at 15 years	LTPA Questionnaire (MAQ)	FM% BIA	Girls with the highest level of moderate activity at baseline had the highest FM% on follow-up.	♂—no association ♀—moderate PA → mean (CI) → $P = 0.01$ Low → 21.8 (21.0; 22.6) High → 23.3 (22.5; 24.1)	Low or high level of activity according to the median value of the corresponding activity within their sex and age strata.	Tanner stage and age, The WC has also been adjusted for height at baseline.
				Change in PA			Girls who increased the level of moderate PA had lower mean FM%, compared with those decreased moderate PA.	♂—no association ♀—Moderate PA → mean (CI) → $P = 0.03$ Decreased → 24.1 (22.2; 25.3) Increased → 21.4 (20.1; 22.7)	Four groups according to change in PA on baseline and follow-up: decreased, maintained low, maintained high and increased.	

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Table 2 *(continued)*

Author(s) / year	Sample	Age(s) baseline (years)	Age(s) follow-up (years)	Type of long-term analysis	Exposure / instrument	Outcome / instrument	Main results	Effect magnitude	Comparison group	Adjustment
Stevens et al 2007	984 females	11	14	Change in PA	Total PA Accelerometry	FM% Equation	Girls at the 85th percentile (mean 31.8 minutes of MVPA/day) had the FM 2.26% percentage points lower than girls in the 15th percentile (13.7 minutes of MVPA/day).	♀—β (CI): –0.1249 → (–0.1818; –0.0679) β (CI) for 85th vs. 15th percentile: –2.26 → (–3.29; –1.23)	MVPA (min-day) The cutpoint for MVPA was 4.6 METs.	Race, community and school within community.
Fulton et al 2009	678 males and females	8, 11, and 14	12, 15, and 18	Change in PA	Total PA Questionnaire (7-d PA recall)	FM% (FMI) BIA	Each increments in MVPA (100 min/day) there is a decreased of 0.14 (kg/m2) in FMI on adolescents between 10 and 18 years.	♂ and ♀— β (± SD) → –0.1359 (0.0466) → $P < 0.05$	MVPA (min/day), The cutpoint for MVPA was ≥ 3.0 METs.	Gender, race, age, biological maturity and interaction between gender and biological maturity.
Völgyi et al 2011	201 females	10 to 13	17 to 20	Change in PA	LTPA Questionnaire (PACE +)	FM% DXA	Participation in 5 hours of LTPA have a significant effect on FM%.	♀—(mean ± SD) → $P = 0.040$ Maintained high—29.9(1.01) High to Low—33.1 (1.03) Low to High—29.5 (1.03) Maintained low—32.4 (0.97)	Four groups according to change maintenance in PA on baseline and follow-up: maintained high, high to low, low to high and maintained low. PA level based on LTPA score.	Height in the 7th year of follow up.

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Table 2 *(continued)*

Author(s) / year	Sample	Age(s) baseline (years)	Age(s) follow-up (years)	Type of long-term analysis	Exposure / instrument	Outcome / instrument	Main results	Effect magnitude	Comparison group	Adjustment
Barnett et al 2013	1195 All (577 males and 618 females)	12	19	Change in PA	Total PA Questionnaire (7-d PA recall)	FM% Equations Slaughter's	In earlier adolescence, a yearly decline of 1 bout of VPA was associated with an increase of 0.47 units of body fat% in girls but not in boys. Similarly, a yearly decline of 1 bout of MVPA was associated with an increase of 0.19 units of body fat% in girls only.	Earlier adolescence (12–15y) MVPA bouts/week ♂—Rate of MVPA decline → no association ♀—Rate of MVPA decline → 0.189 (0.021; 0.357) VPA bouts/week ♂—Rate of VPA decline → no association ♀—Rate of VPA decline → 0.468 (0.015; 0.921)	MVPA and VPA decline of 1 bout for week between 12–15 years.	Age and adiposity at the beginning of follow-up time.
							In later adolescence, rates of VPA or MVPA decline were not associated with body fat% among girls. Among boys, a yearly decline of 1 bout of MVPA per week was associated with an increase of 0.38 units of body fat%, whereas no association was observed for VPA	Later adolescence (15–18y) MVPA bouts/week ♂—Rate of MVPA decline → 0.376 (0.050; 0.702) ♀—Rate of MVPA decline → no association VPA bouts/week ♂—Rate of VPA decline → no association ♀—Rate of MVPA decline → no association	MVPA and VPA decline of 1 bout for week between 15–18 years.	
Cohen et al 2014	265 females	13	18	Predictive PA at 13 years → FM% at 18 years	Total PA Accelerometry	FM% BIA	Each additional minute of increase in vigorous PA per day was associated with a decline of nearly 0,1% in BF. Moderate PA was not associated with BF%.	Vigorous PA → β (SE) –0.09 (0.04) → $P < 0.05$ Moderate PA → no association	Minutes per day of moderate and vigorous PA. Each increment of 1 minute per day.	Age, race, mother's education and neighborhood households in poverty.

Abbreviations: SF, skinfold; SSF, sum of skinfolds; SB, skinfold subscapular; TR, skinfold triceps; WC, waist circumference; BF, body fat; FM, fat mass; FM%, fat mass percentage; FMI, fat mass index; PA, physical activity; LTPA, leisure time physical activity; MVPA, physical activity moderate to vigorous; MET, Metabolic equivalent, unit used to estimate the metabolic cost (oxygen consumption) of physical activity; MAQ, Modifiable Activity Questionnaire; HAQ, Habitual Activity Questionnaire; PAC-C, Physical Activity Questionnaire for Children; PAC-A, Physical Activity Questionnaire for Adolescent; Baecke, Questionnaire of Baecke for Measurement of a Person's Habitual Physical Activity Patient; PACE+, Centered Assessment and Counseling for Exercise and Nutrition; 7-d PA recall, Seven Day Physical Activity Recall adapted; DXA, Dual-energy X-ray Absorptiometry; BIA, Bioimpedance; OR, Odds Ratio.

of how PA was measured (by questionnaire or accelerometer), and it was also stronger in those studies that assessed changes in PA levels.

New studies on the effects of PA on BF will find more clearly and precisely the relation between PA practice and BF during adolescence if they use measures of BF that more precisely represent the total BF, such as FM or FM%, and measures of PA level which allow to obtain the levels of different intensity of PA (ie, light, moderate, and vigorous). Other relevant methodology aspects to be considered in longitudinal studies are including subjects specifically in adolescence, having more than 1 PA practice measurement during the follow-up period, and expressing and analyzing the PA variables preferably taking into account the change in PA level during the periods assessed.

There are a few aspects in this review which may be considered as limitations to the article and are discussed as follows. The fact that the review was carried out by only 1 of the authors might have caused a selection bias. However, when a doubt emerged regarding inclusion or exclusion of any article, the other authors were consulted in order to make a decision. In addition, searches carried out by only 1 author had already been conducted in other studies without compromising the quality.[83] The fact that the search was conducted only in Pubmed may be another limitation regarding the scope of the search. However, we understand that Pubmed represents one of the largest datasets of published articles in health developed around the world and includes abstracts for the majority of recent records. Furthermore, it also encompasses a considerable amount of other datasets. Thus, we believe that the search in this dataset, in addition to the inspection of the references of selected articles, would return the total of published articles selected for the period. Besides, publications regarding cohort longitudinal studies are scarce, especially in low- and middle-income countries. The decision for not carrying out a search using gray literature was done based on 2 assumptions: 1) the search process is logistically complicated and demands time as unpublished data may be only obtained by contacting the authors; and 2) the fact that this kind of search does not allow to establish the existing amount to be found and does not ensure maximal scope. Thus, we have chosen to consider only published data which are available either in datasets or in easily accessed online journals. The last aspect to consider as a possible limitation of this review is the potential language bias. However, the database PubMed/Medline includes abstracts and articles in all areas of health around the world. In addition, studies published in other languages usually come with abstracts written in English, and no situation such as this was identified in our review process. Thus, we believe that the language bias has no relevance to this review.

Conclusion

The main conclusions of this systematic review are 1) PA practice has a protective effect on BF, 2) PA practice at higher intensities promotes a greater protector effect on BF in both sexes, 3) the relation between PA and BF is influenced by the way BF develops and is distributed between the genders during adolescence, and 4) the longitudinal analysis models that consider changes in PA levels throughout adolescence are more appropriate to establish a relation between PA practice and BF than those that analyzed PA only at the baseline.

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