Review Article

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Associations between total physical activity levels and academic performance in adults: A systematic review and meta-analysis

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Abstract:

Physical activity has been associated with positive health-related outcomes. Physical inactivity, conversely, has been associated with several negative health outcomes. One topic that has been consistently examined is the relationship between physical activity and academic performance in children; however, studies that involve university-level students have not been aggregated to date. It is therefore the aim of this systematic review to examine the relationship between physical activity and academic performance in university-level students.This systematic review was conducted in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines and included any study published until September 2023 that examined associations between physical activity and any measure of academic performance. SPORTDiscus, ERIC, the British Education Index, Scopus, Embase, Web of Science, and PubMed were searched. A random effects meta-analysis was also undertaken, and risk bias was assessed using the Newcastle Ottawa Scale.After screening, 36 studies were included, with six studies being included in the meta-analysis. The meta-analysis found a significant association between physical activity (high versus low) and academic performance (high versus low performers) (odds ratio = 3.04; 95% CI = 1.84-5.02; $P \leq 0.001$; $I^2 = 49.62$). These results, however, were deemed to be of low credibility. The narrative analysis yielded mixed results, with 50% of studies reporting positive associations and the remaining studies reporting no significant associations. This trend did not differ depending on the subjective or objective measurement of physical activity.Although this review found meta-analytic significant associations between physical activity and academic performance, these results should be treated with caution, as the remaining studies yielded mixed results. Future studies should aim to focus on objective measurements of physical activity where possible to further explore this potential relationship.

Keywords:

Academic, physical activity, sedentary behavior, university

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Introduction

Physical activity (PA) is typically defined as any type of bodily movement that results in energy expenditure[1] and has been consistently positively associated with health-related outcomes, including, for example, mortality,[2] several mental health outcomes,[3] and specific cancers,[4] across several age groups. Furthermore, systematic reviews have shown that even bouts of PA of short duration (less than 10 min) yield numerous positive health outcomes, including, for example, favorable lipid profiles, cardiovascular risk scores, and blood pressure.[5] On the other hand, physical inactivity, defined as not meeting national PA recommendations,[6] is a recognized global pandemic,[7] is negatively associated with several health outcomes, and has been estimated to directly contribute to 5.3 million deaths per year.[8] These negative health outcomes are not only related to the adult

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population: a recent review by van Sluijs and colleagues suggests that adolescent physical inactivity contributes to the global health burden of disease, including cardiometabolic and mental health disorders.[9] One topic that has been consistently examined is the relationship between PA and academic performance, especially in children. The results, however, are inconclusive: one systematic review[10] found that, from 251 outcomes between school-based PA and academic performance, 51% of outcomes yielded significant positive associations, whereas 48% were non-significant (the remaining 1% yielded negatively significant associations). One of the reasons why this review may have found inconclusive results is because only school-based PA was measured. It is plausible to hypothesize that overall levels of PA (of which school-based PA is one domain) may influence academic performance. Indeed, a more recent systematic review concluded that PA interventions had a positive effect on academic performance in children and pre-adolescents; they also noted the possibility of a dose-response relationship.[11] The possible mechanisms of this potential link between PA and academic performance are related to general increases in cognitive performance, which then influences academic performance in school, particularly if the PA involves multiple components.[12]

Several studies have also been conducted on university students. For example, in a large US-based cohort study, moderate-vigorous PA was associated with significantly higher grade point averages (GPA).[13] This was also the case for a more recent longitudinal study that concluded that levels of PA were significantly associated with academic performance, although the effect size was small.[14] To date, however, the authors can find no literature that has attempted to synthesize these studies. It is the aim of this systematic review, therefore, to review and synthesize all available evidence examining the relationship between total PA and academic performance in university-level students. Specifically, this review aims to answer the following research question: Are levels of total PA correlated with academic performance in adult university-level students?

The potential benefits of this review are numerous. For example, it has the potential to inform PA interventions in adults who are studying. Moreover, it will highlight areas in which there is a saturation in the literature and areas with a paucity of studies, therefore, informing future research.

Materials and Methods

Search strategy

This systematic review was conducted in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[15] and following a pre-written protocol.[16] A total of seven databases (SPORTDiscus, ERIC, the British Education Index, Scopus, Embase, Web of Science, and PubMed) were searched on November 09, 2023, using the following search terms:

(Academic AND (grade OR performance OR achievement)) AND (physical activity OR sedentary OR exercise OR sport) NOT (children OR adolescents).

Data extraction and risk of bias

Following the search, results were imported into a reference manager, where duplicates were automatically excluded. The titles and abstracts of remaining studies were then screened independently by four study authors (MT, JH, NK, and BL), using the following inclusion and exclusion criteria, using the PICO protocol:

- Participants/population: Studies with university-level students, who are aged 18 or older. If studies included both adults and children, the article was only included if stratified adult data were presented/available through correspondence with the lead author.
- Interventions/exposure: Physical activity – any measure of total PA will be included (e.g. survey-based measures, such as the International Physical Activity Questionnaire and objective measures, such as accelerometry). Studies that measured solely levels of exercise, such as university-level sport attendance or gym attendance, were excluded.
- Comparators/control: Because this review will include only observational studies, no comparators/controls are required.
- Outcome(s): Academic performance of any kind. This could include GPA, mean grades, continuance to further study (for example, from year 1 to year 2 undergraduate), grade improvement, and academic score. No type of academic performance will be excluded in this review.

The types of study to be included in this review were observational only, including cross-sectional, cohort, and case-control. Interventional studies (such as randomized controlled trials) were excluded. Reference lists of studies (including any reviews found) were also checked for relevant studies.

Following title and abstract screening, full-text articles were reviewed by four members of the study team (MT, NK, JH, and BL) according to the inclusion and exclusion criteria. Data were then extracted onto a custom data extraction template by two independent authors (MT and LS) and assessed for risk of bias using the Newcastle-Ottawa Scale (NOS) – modified for cross-sectional studies.[17] The NOS has been well validated and used across several studies[18,19] and creates a continuous-level risk of bias score, with a maximum score of 9 and a minimum score of 0.

Data synthesis

If data were suitably homogeneous (particularly regarding the methods of measuring PA and academic achievement), a meta-analysis was undertaken. The meta-analysis pooled effect sizes and 95% confidence intervals (CIs) in a random effects model, using the DerSimonian-Laird methodology, weighted by the inverse variance.[20] Publication bias was assessed using the Egger statistic,[21] using a conservative $P < 0.10$ to determine if publication bias was present, and heterogeneity was measured using the I^2 statistic,[22] using categories proposed by Higgins[22] to classify high (75-100%), moderate (50-75%), or low (0-50%) heterogeneity. Moreover, to determine whether the meta-analytic effect size could be applied at a population level, the prediction interval (PI) was also determined. All statistical tests were conducted using SPSS Version 28.

All non-meta-analyzable results were synthesized narratively. The credibility of the evidence was determined using the GRADE criteria.

Results

The initial database searches yielded a total of 8,302 results, of which 2,739 were automatically removed as duplicates, leaving a total of 5,563 studies to be reviewed on the title and abstract level. Following title and abstract screening, 186 studies were retained for full-text retrieval and review. Following full-text screening, a further six studies were identified from reference lists, making the total number of full-text articles screened 192. Following full-text screening, 36 studies were retained and are included in this review. Of these 36 studies, six were deemed homogeneous enough to be included in the meta-analysis. The full PRISMA flowchart can be found in Figure 1.[23]

Full demographic variables of included studies can be found in Table 1. In brief, a total of 36,271 participants were included, with a median *n* of 297 per study. The median percentage female per study was 70%, and most studies (30/36; 83.3%) included university campus-based students (with five studies not reporting the location of students, and the remaining one study measuring distance learners). Furthermore, most of the studies' participants studied at undergraduate level (27/36 studies; 75%), with the remaining studies examining doctoral students (5/36; 13.9%) and postgraduate students (one study; 2.8%). Three studies (8.3%) failed to report on the level of study. Regarding study design, most studies (30/36; 83.3%) were cross-sectional, with three (8.3%) longitudinal studies, two (5.6%) cohort studies, and one (2.8%) case-control study. Regarding the measurement of PA, 33 studies (91.7%) used a subjective measurement tool, whereas three studies (8.3%) employed objective methods of measuring PA. Of the subjective tools used, the most common were unvalidated questions (13/36;

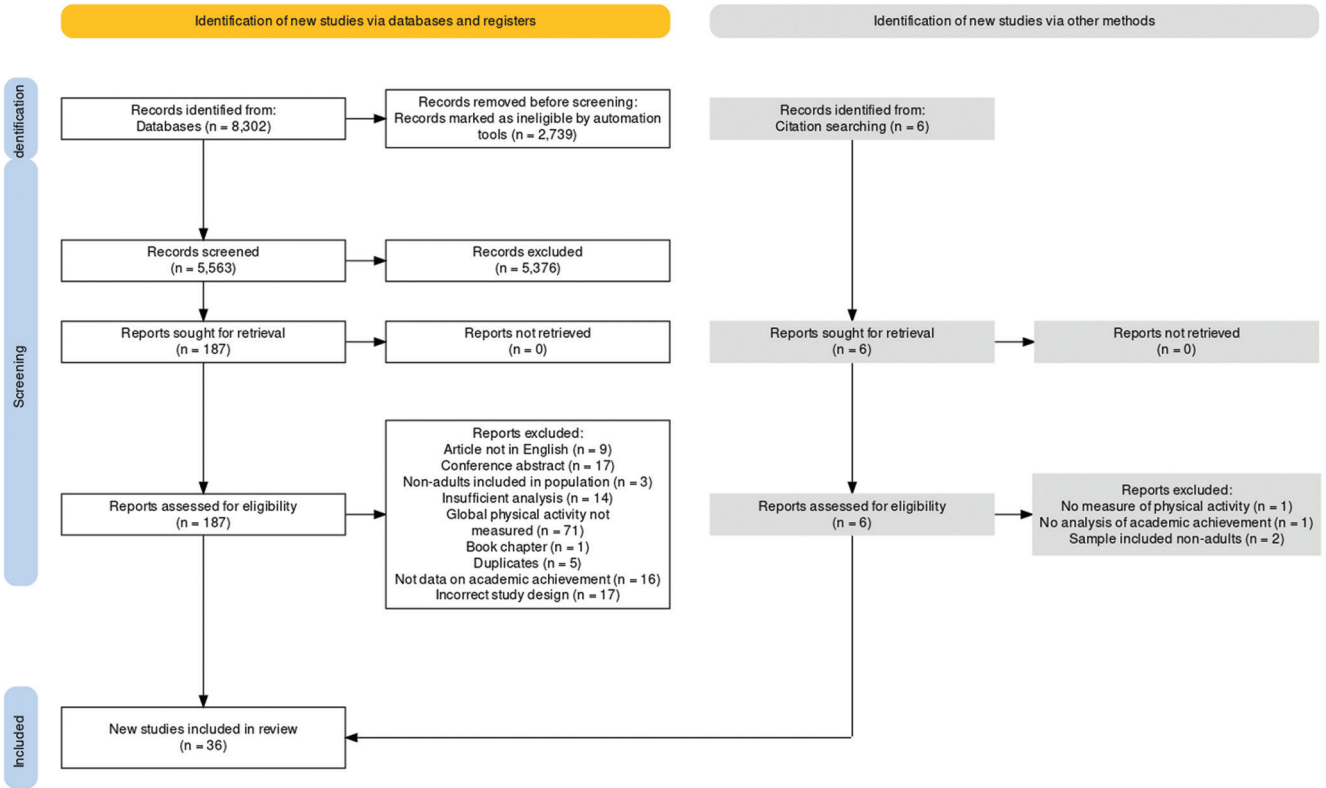

Figure 1: PRISMA flowchart

Table 1: Descriptive characteristics of included studies

Author (s)	Study type	Country	Population demographics	Location of student (campus/ distance learners)	Method of measuring physical activity (objective/subjective)	Type and method of measuring academic achievement (objective/subjective)	Summary of physical activity results	Included in meta-analysis?
Aaltonen *et al.*[24]	Cross-sectional	Finland	*n*=2,543 Mean age NR Percentage female NR	NR	Survey assessment using unvalidated question NR (subjective)	GPA gathered from self-report (subjective)	Significant positive association (although mediated by genetic factors)	No
Al-Drees *et al.*[25]	Cross-sectional	Saudi-Arabia	*n*=409 Mean age=21.3 (SD=1.5) Percentage female NR	Doctoral (campus)	Survey assessment using unvalidated question NR (subjective)	GPA gathered from self-report (subjective)	Conducting PA versus no PA is significantly associated with GPA	Yes
Al-Momani[26]	Cross-sectional	Saudi-Arabia	*n*=576 Mean age=21.9 (SD=1) 45.8% female	Undergraduate (campus)	Survey assessment using HPLP-II (subjective)	GPA gathered from self-report (subjective)	No significant relationship found.	No
Alnofaiey *et al.*[27]	Cross-sectional	Saudi-Arabia	*n*=2,819 Mean age=22.7 (SD=2.3) 66.5% female	Undergraduate (campus)	Survey assessment using G-PAQ (subjective)	GPA gathered from student records. (objective)	Low levels of PA were independently associated with low GPA (controlled for age, gender, chronic disease, and anxiety)	No
Alhaqbani *et al.*[28]	Cross-sectional	Saudi-Arabia	*n*=317 Mean age NR Percentage female NR	Undergraduate (campus)	Survey assessment using IPAQ (subjective)	GPA (method of collecting data NR)	No significant relationship found.	No
Alhazmi *et al.*[29]	Cross-sectional	Saudi-Arabia	*n*=379 Mean age NR (range 18-30) Percentage female NR	Undergraduate (campus)	Survey assessment using unvalidated question NR (subjective)	GPA gathered from self-report (subjective)	No significant relationship found.	No
Aljehani *et al.*[30]	Cross-sectional	Saudi-Arabia	*n*=328 Mean age=21 (SD=1.9) 100% female	Undergraduate (campus)	Survey assessment using unvalidated question NR (subjective)	GPA gathered from self-report (subjective)	No significant relationship found.	No
Almoajel *et al.*[31]	Cross-sectional	Saudi-Arabia	*n*=310 Mean age NR 100% female	Undergraduate (campus)	Survey assessment using the WHO GPAS (subjective)	GPA gathered from self-report (subjective)	PA appears to be related to academic performance among students of sciences colleges, but not humanist or medical colleges	No
Ardila and Gómez-Restrepo[32]	Cross-sectional	Columbia	*n*=1,534 Mean age=21 (SD=3) 62% female	Doctoral (campus)	Survey assessment using unvalidated question NR (subjective)	GPA gathered from student records. (objective)	Being physically inactive increased the odds of having low academic achievement by 5	Yes
Ardila and Gómez-Restrepo.[33]	Cross-sectional	Columbia	*n*=218 Mean age NR 72% female	Doctoral (campus)	Survey assessment using unvalidated question NR (subjective)	GPA gathered from student records. (objective)	PA protects against lower GPA	Yes
Ardila and Gómez-Restrepo[34]	Case control	Columbia	*n*=30 Mean age=23 (SD=3) 62.9% female	Undergraduate (NR)	Survey assessment using unvalidated question NR (subjective)	GPA (method of collecting data NR)	PA protects against lower means of GPA	Yes

Contd...

Table 1: Contd...

Author (s)	Study type	Country	Population demographics	Location of student (campus/ distance learners)	Method of measuring physical activity (objective/subjective)	Type and method of measuring academic achievement (objective/subjective)	Summary of physical activity results	Included in meta-analysis?
Bellar *et al.*[35]	Cross-sectional	USA	*n*=740 Mean age=21.2 (SD=4.7) 41.5% female	Undergraduate (campus)	Survey assessment using the leisure and physical activity questionnaire (subjective)	GPA gathered from self-report (subjective)	Higher levels of aerobic activity associated with higher GPAs, however weightlifting activity was not	No
Beltrán-Velasco *et al.*[36]	Cross-sectional	Spain	*n*=172 Mean age=23.5 (SD 5.4) 71.8% female	Undergraduate (campus)	Survey assessment using unvalidated question: 'how many hours per day in movement' (subjective)	Average grade across subjects (method of collecting data NR)	No significant relationship found.	No
Chung *et al.*[37]	Cohort	Malaysia	*n*=244 Mean age=21.3 (SD 1.8) 76.2% female	Undergraduate (campus)	Survey assessment using IPAQ-SF (subjective)	GPA gathered from student records. (objective)	No significant relationship found.	Yes
da Silva *et al.*[38]	Cohort	Canada and Malaysia	Canada cohort: *n*=224 Mean age=18.2 (SD 2.2) Malaysia cohort: Mean age=19.0 (SD=0.2) Percentage female NR	Undergraduate (campus)	Survey assessment using HPLP-II (subjective)	GPA gathered from student records. (objective)	Higher PA predicted lower academic performance, but only in Canadian students.	No
Deliens *et al.*[39]	Longitudinal	Belgium	*n*=101 Mean age=18 (SD=0.6) 77% female	Undergraduate (campus)	Survey assessment using Flemish Physical Activity questionnaire) (subjective)	GPA gathered from student records. (objective)	No significant relationship found.	No
El Ansari and Stock[40]	Cross-sectional	Egypt	*n*=3,271 Mean age NR 52.5% female	Undergraduate (campus)	Survey assessment using unvalidated question NR (subjective)	Subjective academic performance compared with peers (subjective)	Students who achieved vigorous PA and moderate-or-vigorous PA guidelines were more likely to report better academic performance.	No
Felez-Nobrega *et al.*[41]	Cross-sectional	Malaysia	*n*=120 Mean age=20.6 (SD 2.3) 53.3% female	Undergraduate (campus)	ActivPAL3 micro device (objective)	GPA gathered from student records. (objective)	No significant relationship found.	No
Gijselaers *et al.*[42]	Longitudinal	Netherlands	*n*=1,100 Mean age=35.7 (SD=11.0) 63.5% female	Undergraduate (distance learners)	Survey assessment using Short Questionnaire to Assess Health-enhancing physical activity (subjective)	Study progress - number of successfully completed study modules in 14 months (objective)	No significant relationship found.	No
Gonzalez *et al.*[43]	Cross-sectional	USA	*n*=92 Mean age NR 73% female	Postgraduate (campus)	Survey assessment using IPAQ-SF (subjective)	GPA gathered from self-report (subjective)	No significant relationship found.	No

Contd...

Table 1: Contd...

Author (s)	Study type	Country	Population demographics	Location of student (campus/ distance learners)	Method of measuring physical activity (objective/subjective)	Type and method of measuring academic achievement (objective/subjective)	Summary of physical activity results	Included in meta-analysis?
Kayani *et al.*[44]	Cross-sectional	Pakistan	*n*=358 Mean age NR Percentage female NR	NR	Survey assessment using IPAQ-SF (subjective)	GPA (method of collection NR)	Self-esteem and depression were found to be significant mediators between physical activity and academic performance	No
Kwok *et al.*[45]	Longitudinal	Hong Kong	*n*=15 Mean age=26.9 (SD=3.1) 73.3% female	NR (campus)	Actigraph device (objective)	GPA gathered from student records. (objective)	Objective physical activity was significantly correlated with academic performance	No
Lipošek *et al.*[46]	Cross-sectional	Slovenia	*n*=297 Mean age=20.5 (SD=0.7) 61.6% female	Undergraduate (campus)	Survey assessment using IPAQ (subjective)	Admission to 2nd year of study (objective)	No significant relationship found.	No
Madihah *et al.*[47]	Cross-sectional	Malaysia	*n*=94 Mean age NR 55% female	Undergraduate (campus)	Survey assessment using IPAQ (subjective)	GPA gathered from self-report (subjective)	No significant relationship found.	Yes
Mansfield *et al.*[48]	Cross-sectional	USA	*n*=164 Mean age=20.3 (SD NR) 38% female	Undergraduate (campus)	Survey assessment using the self-control scale (subjective)	GPA gathered from self-report (subjective)	Sig relationship between PA as a domain of self-control and self-reported GPA	No
Moawd *et al.*[49]	Cross-sectional	NR	*n*=100 Mean age NR 100% female	Undergraduate (campus)	Survey assessment using IPAQ-SF (subjective)	GPA gathered from student records. (objective)	Significant trends in GPA score for low, moderate, and high levels of PA	No
Nemec *et al.*[50]	Cross-sectional	USA	*n*=63 Mean age=21 (SD NR) 65% female	Doctoral (campus)	Fitbit device (objective)	GPA gathered from student records. (objective)	No significant relationship found.	No
Nuevo *et al.*[51]	Cross-sectional	Spain	*n*=55 Mean age=21.2 (SD 2.9) Percentage female NR	Undergraduate (campus)	Survey assessment using G-PAQ (subjective)	GPA gathered from student records. (objective)	No significant relationship found.	No
Ong *et al.*[52]	Cross-sectional	Australia	*n*=1543 Mean age=25 (SD=7.9) 70.6% female	Undergraduate (NR)	Survey assessment using Active Australia survey (subjective)	GPA gathered from self-report (subjective)	No significant relationship found.	No
Reuter *et al.*[14]	Cross-sectional	USA	*n*=614 Mean age 19.6 (SD=1.4) 78.5% female	Undergraduate (campus)	Survey assessment using unvalidated question NR (subjective)	GPA gathered from self-report (subjective)	Significant positive associations found.	No
Satti *et al.*[53]	Cross-sectional	Pakistan	*n*=219 Mean age NR Percentage female NR	Undergraduate (campus)	Survey assessment using G-PAQ (subjective)	Most recent pathology test score gathered from student records	Significant relationship found between PA and most recent test scores	No

Contd...

Table 1: Contd...

Author (s)	Study type	Country	Population demographics	Location of student (campus/ distance learners)	Method of measuring physical activity (objective/subjective)	Type and method of measuring academic achievement (objective/subjective)	Summary of physical activity results	Included in meta-analysis?
Trockel *et al.*[54]	Cross-sectional	USA	*n*=184 Mean age NR Percentage female NR	Undergraduate (campus)	Survey assessment using unvalidated question NR (subjective)	GPA gathered from student records. (objective)	Aerobic activity and strength training we not correlated in raw analysis, but strength training was a significant predictor of academic achievement in the multiple regression model	No
Wald *et al.*[13]	Cross-sectional	USA	*n*=16,095 Mean age=20 (SD=1.5) 70.3% female	Undergraduate (NR)	Survey assessment using unvalidated question: 'how many hours per day in movement' (subjective)	GPA gathered from self-report (subjective)	Meeting the national guidelines for moderate-vigorous physical activity was a significant positive predictor of grade average However, the addition of meeting (or exceeding) the guidelines for strength training was not significant. If the moderate-vigorous physical activity recommendation was met, grade average was higher by 0.03 points	No
Wehler *et al.*[55]	Cross-sectional	USA	*n*=803 Mean age=NR 75.3% female	Undergraduate (campus)	Survey assessment using IPAQ-SF (subjective)	GPA gathered from student records. (objective)	No significant relationship found.	No
Xu and Sansgiry[56]	Cross-sectional	USA	*n*=140 Mean age=24.6 (SD=2.9) 70% female	Undergraduate (campus)	Survey assessment using IPAQ (subjective)	GPA gathered from self-report (subjective)	No significant relationship found.	No
Zain *et al.*[57]	Cross-sectional	Saudi-Arabia	*n*=NR Mean age NR Percentage female NR	Doctoral (campus)	Survey assessment using unvalidated question NR (subjective)	NR	No significant relationship found.	No

36.1%), followed by forms of the International Physical Activity Questionnaire (IPAQ; 9/36; 25%). Regarding the measurement of academic achievement, most of the included studies (30/36; 83.3%) used GPA as their metric. The mean NOS score was 6.1 ± 1.9; median score = 6; range, 1-9; see Table 2 for full scoring information.

Meta-analysis

Six studies[25,32-34,37,47] were homogeneous enough to be included in the meta-analysis. The independent variables for included studies were meeting or not meeting recommended PA guidelines (all measured with subjective measures of PA), with the dependent variable being high versus low academic achievers. The pooled effect size as an OR was 3.04 (95% CI 1.84-5.02; $P \leq 0.001$), with $I^2 = 49.62\%$, and a non-significant Egger's intercept ($P = 0.11$). The prediction interval was 3.04 (95% CI 0.76-12.22). Because of the low number of studies, and prediction interval that crossed the null, the credibility of this analysis was deemed as low. The forest plot is shown in Figure 2.

Non-meta-analytic results

Of the 30 studies that were not included in the meta-analysis, mixed results were found regardless of the type of PA measurement, with 50% of studies reporting significant findings and 50% of studies finding no significant associations between PA and academic achievement (this was also the case when stratified between subjective and objective PA measures). A visual representation of these findings can be found in Figure 3.

Campus-based undergraduate students

Articles that examined campus-based undergraduate students yielded largely mixed results. While several

Table 2: Newcastle-Ottawa-Scale scoring for all included studies

Study	Representativeness of the sample	Sample size	Non-respondents	Ascertainment of exposure	Comparability	Assessment of the outcome	Statistical tests	Overall
Aaltonen *et al*.	1	1	NA	1	1	1	1	6
Al-Drees *et al*.	2	1	NR	1	0	1	1	6
Al-Momani	2	1	NR	2	0	2	1	8
Alnofaiey *et al*.	2	1	NR	2	1	2	1	9
Alhaqbani *et al*.	2	1	NR	2	0	2	1	8
Alhazmi *et al*.	1	0	NR	1	0	1	1	4
Aljehani *et al*.	1	1	NR	1	0	1	1	5
Almoajel *et al*.	0	0	NR	2	0	1	1	4
Ardila and Gómez-Restrepo	1	0	NR	1	1	2	1	6
Ardila and Gómez-Restrepo	1	0	NR	1	1	2	1	6
Ardila and Gómez-Restrepo	0	0	NR	1	1	2	1	5
Bellar *et al*.	0	0	NR	2	0	1	1	4
Beltrán-Velasco *et al*.	1	0	NR	0	0	1	1	3
da Silva *et al*.	0	1	NR	2	1	2	1	7
Deliens *et al*.	1	0	NR	2	1	2	1	7
El-Ansari and Stock	2	0	NR	0	0	1	1	4
Felez-Nobrega *et al*.	1	0	NR	2	1	2	1	7
Gijselaers *et al*.	2	0	NR	2	1	2	1	8
Gonzalez *et al*.	1	0	NR	2	0	1	0	4
Kayani *et al*.	1	0	NR	2	1	NR	1	5
Kwok *et al*.	1	0	NR	2	0	2	1	6
Lipošek *et al*.	1	0	1	2	1	2	1	8
Madihah *et al*.	1	1	1	2	1	1	1	8
Mansfield *et al*.	1	0	NR	2	0	1	1	5
Moawd *et al*.	1	0	NR	2	1	2	1	7
Nemec *et al*.	2	0	1	2	0	2	1	8
Nuevo *et al*.	1	0	NR	2	0	2	1	6
Ong *et al*.	2	0	NR	2	1	1	1	7
Reuter *et al*.	1	0	NR	1	0	1	1	4
Satti *et al*.	1	0	1	2	1	2	1	8
Trockel *et al*.	1	0	1	0	0	2	1	5
Wald *et al*.	2	0	1	1	1	1	1	7
Wehler *et al*.	1	0	1	2	0	2	1	7
Xu and Sansgiry	2	0	1	2	1	1	1	8
Zain *et al*.	1	0	NR	0	0	0	0	1
Zamri and Raman	2	1	NR	2	1	2	1	9

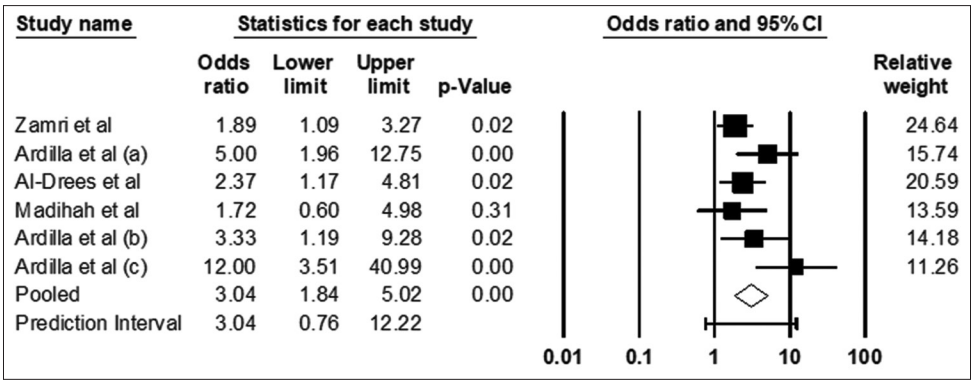

Figure 2: Forest plot showing pooled odds ratio of the association of physical activity and grade point average

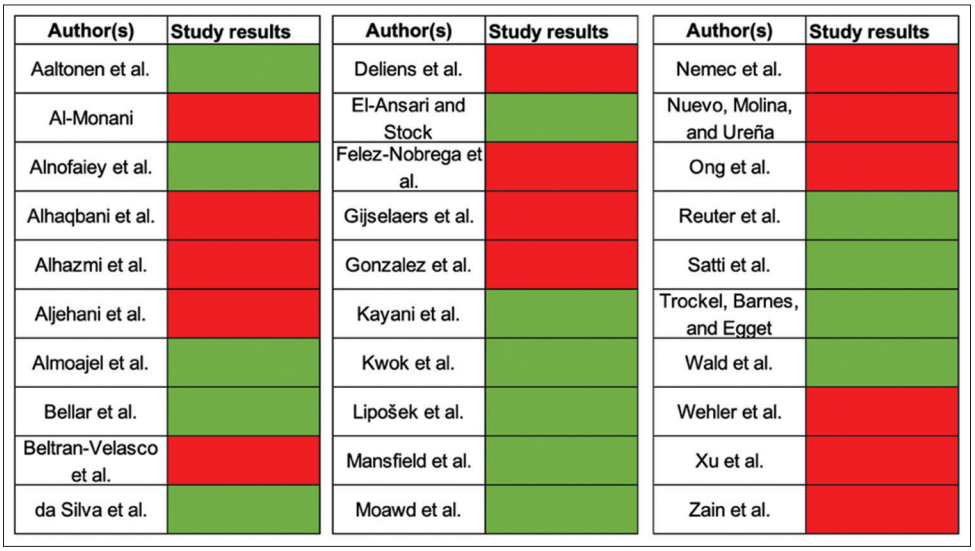

Figure 3: Visual representation of individual study results. Green boxes indicate significant relationships between physical activity and academic achievement. Red boxes indicate the findings of no significant relationships between physical activity and academic achievement

studies reported no significant relationships between PA and academic performance, others reported positive associations, and one study reported a negative association. While most of these studies examined PA through self-report measures, one study[41] used device-measured PA (via the ActivePAL device) and reported that only weekday bouts of sedentary activity that lasted for 10-20 min were positively related to academic achievement, with both light and moderate PA yielding no association. Several studies used self-report measures to determine academic achievement, most of which yielded significant outcomes (57%). Of the studies that used student records as a measure of academic success, most studies (70%) reported significant associations between PA and academic achievement.

Distance-based undergraduate students

One study[42] was found that examined students that were studying a distance learning course, and reported that PA was not associated with academic performance (sedentary behavior, however, was associated with study progress).

Postgraduate students

A total of six studies were found that examined post-graduate students, again with conflicting results. Three studies found no significant relationships, while the other three found significant associations between PA and academic achievement. One study[50] used device-measured PA and found that, although total steps were not a predictor for GPA, those students who decreased their total steps 72 hours before examinations scored significantly higher scores.

Mature students

Ten studies were found that examined PA and academic achievement in mature students, defined as studies with a mean age of over 21 for undergraduate students, and a mean age of over 25 in postgraduate students.[58] Two of these studies used device-measured PA. Kwok *et al*.[45] found a significant correlation between PA and academic achievement, whereas Gijselaers *et al*.[42] found no such association (they did report, however, that more sedentary behavior was a predictor for study progress). Of the other eight studies

that used subjective PA measurements, four (50%) found significant findings.

Discussion

This review aims to report on the current literature examining any associations between PA and academic performance in university students. The meta-analytic results suggest that meeting the WHO PA guidelines[1] is associated with over double the odds of being a high academic achiever. Although there was a high degree of heterogeneity in these results (and therefore should be interpreted with caution), there are several potential mechanisms that could explain these findings. First, PA has been consistently associated with positive mental health outcomes, including lower levels of depression[59,60] and anxiety,[61,62] which could potentially lead to positive academic outcomes. Furthermore, studies have shown that PA is associated with better concentration levels in adolescents.[63] There is a possibility that this could also be the case in adults; however, to date, there is a paucity of studies that examine cognition (including levels of concentration) in adults of working age – the majority of the literature leans towards older adults.[64] Future research should aim to investigate any relationships between PA and concentration, and its potential mediating role in the relationship between PA and academic achievement.

Interestingly, the studies that were not included in the meta-analysis yielded largely conflicting results. This is concurrent with similar reviews that have assessed the relationships between PA and academic achievement in children.[10] It is likely that the key reason for this is the heterogeneity of the measurement of both dependent and independent variables. For example, not only were a wide variety of tools used to measure PA but these were also interpreted in different ways. It has been well reported that the reliability of PA self-report tools is questionable, with most PA questionnaires reporting low-to-moderate levels of reliability.[65] Regarding the reliability of PA questionnaires in university-level student populations, it does appear that these reliability indices differ.[66] The low level of credibility of self-report questionnaires could be another reason why the results in the included studies differed. Only two studies were found that used objective measures to determine levels of PA. Interestingly, these also reported conflicting results, with one study reporting significant findings and the other study finding no significant associations. Another possible reason for this is the heterogeneous outcome measures used.

Several articles included in this review used GPA as an outcome measure of academic achievement. However, several studies used self-report to gather the information. There is the possibility that social desirability is a factor when reporting academic scores – indeed, it has been consistently shown that participants systematically score questionnaires more highly if they think this is what (a) is more socially desirable, and (b) they think the investigator wants.[67,68] Concurrently, it has been shown that respondents underreport socially less-acceptable answers (in this case, such as lower academic achievement).[68,69] Although this may play a part in the mixed results from the studies included in this review, the studies that used objective forms of academic achievement measurement (such as accessing university records) also yielded conflicting results. It is therefore difficult to conclude with a high degree of certainty if PA is associated with academic achievement – more studies are needed that use homogeneous measurement tools (and using homogeneous interpretations of these tools).

Two studies in this review found significant associations between sedentary behavior and academic achievement. Although beyond the scope of this review, sedentary behavior could be a mediating factor in the PA academic achievement relationship. Indeed, the results of studies indicate that sedentary behavior could be positively associated with academic performance, which could be because studying is often a sedentary activity and students could be studying for their exams more in this period, especially before exams. Further research is warranted to examine this possible link further.

Very few included studies considered confounding/mediating variables in their analyses, which, again could explain the conflicting findings. Future research should aim to control for potential confounding variables (such as anxiety, depression, and sedentary behavior, all found to correlate with metrics of academic achievement) to ascertain more robust results.

Only one study in this review was found that examined the relationship between PA and students studying distance learning courses. Although this study found no significant relationship between PA and academic achievement and had a large sample size (n = 1,100), this cannot be concluded with a high degree of certainty due to the paucity of further studies. Distance learning at universities increased exponentially during the COVID-19 pandemic, and in the period of time after the COVID-19 pandemic,[70] a significant increase in both the number of distance learning courses offered by institutions globally and the number of students studying through distance learning has increased.[71] Future research should aim to recruit distance learners to ascertain any links between PA and academic achievement in this cohort.

Although there is suggestive meta-analytic evidence of an association between PA and academic achievement, there is no evidence of consistent associations across

the breadth of the remaining literature. Despite these findings, PA has been consistently associated with several positive outcomes, both physiologically and mentally. It is therefore recommended that undergraduate students still aim to partake in PA to achieve these benefits and potentially enhance their academic performance, pending further robust research.

The results of this study should be considered within its limitations. First, the heterogeneous dependent and outcome variables mean that the results of this review should be applied cautiously. Second, the articles retrieved were limited to English, so relevant literature written in other languages may have been missed. The cross-sectional design of both the meta-analysis and the majority of non-meta-analyzed studies precludes the determination of causation. Longitudinal studies are recommended to examine any causal links. There is also the possibility of publication bias in the results, although just as many null findings were found as significant findings, so this is unlikely. Moreover, studies from several countries were included in this review – cultural differences between countries may be a factor regarding the null results found.

Conclusion

This review has found suggestive significant evidence that reaching PA guidelines increases the chances of higher academic achievement (versus low academic achievement) in university students. Other studies reviewed in this area reported largely conflicting results, although this could be because of high heterogeneity across studies. Future studies should aim to use homogenous objective measures where possible to determine the links between academic achievement and PA, with the consideration of potential moderating factors, such as anxiety and sedentary behavior. It is recommended that academic institutions continue to promote PA to maximize the chances of both physical and mental health, and potentially academic success.

Ethical considerations
Ethical clearance not required for review studies.

Code of ethics
Code of ethics is not required for review articles.

Authors contribution
MT: concept; design; literature search; literature screening; data extraction; statistical analysis; manuscript drafting and editing

NK; design; literature screening; manuscript editing and review

BL; design; literature screening; manuscript editing and review

LS; design; data extraction; statistical analysis; manuscript editing and review

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There are no conflicts of interest.

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