Biological determinants of physical activity across the life course: a “Determinants of Diet and Physical Activity” (DEDIPAC) umbrella systematic literature review.

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Abstract

Background. Despite the large number of studies and reviews available, the evidence regarding the biological determinants of physical activity (PA) is inconclusive. In this umbrella review, we summarized the current evidence on the biological determinants of PA across the life course, by pooling the results of the available systematic literature reviews (SLRs) and meta-analyses (MAs).

Methods. We conducted an online search on MEDLINE, ISI Web of Science, Scopus and SPORTDiscus databases up to January 2018. SLRs and MAs of observational studies that investigated the association between biological determinants of PA and having PA as outcome were considered eligible. The extracted data were assessed based on the importance of the determinants, the strength of evidence and the methodological quality.

Results. We identified 19 reviews of which most were of moderate methodological quality. Determinants that were studied most frequently among all ages and demonstrated evidence suggesting a positive association to PA were younger age, being male, higher health status and higher physical fitness levels. Among adults, normal birth weight was found to be positively associated to PA with convincing strength of evidence, while findings among adolescents were inconsistent and with limited strength of evidence.

Conclusions. Different social or behavioral factors may contribute to the decrease of PA with age and among females versus males, and creating programmes targeted at diverse ages, female population and adults with abnormal birth weight is recommended. Future studies should use prospective study designs, standardized definitions of PA and objective measurement methods of PA assessment.
Key Points:

- Younger age, being male, higher health status and higher physical fitness levels suggested a positive association with physical activity.
- Normal birth weight was positively associated with physical activity among adults.
- Different social and behavioral factors contribute to the decrease of physical activity with increasing age.

Keywords: physical activity; biological determinants; umbrella systematic review

Main Text

Background

The World Health Organization (WHO) has developed global recommendations to increase the amount of physical activity (PA) in the general population, following the abundant evidence of the positive effects of PA on the maintenance of cardiovascular health and metabolic index, thus being of high importance for the prevention and the management of the non-communicable diseases (NCDs) [1]. Since NCDs constitute a large part of the worldwide disease burden, prevention programs with the effective incorporation of PA are of paramount importance [1–3].

Biological determinants can be all the individual characteristics of a person that have biological background, including: genetics, family predisposition, pathology, health status, anthropometry, body mass index (BMI)/adiposity, birth weight, physical fitness levels, age, sex, ethnicity, etc [4]. Even though some of them are non-modifiable, they influence the patterns of PA interacting with other factors on multiple levels [5–8]. Because of that, they
should be considered when investigating PA participation and introducing new interventions of PA.

Several original studies, systematic literature reviews (SLRs) and meta-analyses (MAs) evaluating the determinants promoting or inhibiting PA participation are available in the literature. Specifically concerning biological determinants of PA, a number of primary epidemiological studies, SLRs and MAs, and two umbrella reviews [9,10], the last concerning only young populations, have been published. According to all these studies, lower age and being male were generally found to be positively associated with PA in most of them and there is inconsistent evidence for the association between PA and several additional biological determinants (e.g. BMI, ethnicity, health status and family risk). Among studies there is wide variability of study aims and measurement methods and classifications used in assessing PA. This produces variability of study results and as a result, a lack of precise evidence about the biological determinants of PA participation. Furthermore, in order to establish experimental evidence related to PA, a clear understanding of associations or predictive relationships between determinants is needed. [11]

Hence, the aim of this umbrella systematic review is to give an overview of the studies investigating biological determinants influencing PA across the life course by systematically reviewing the available evidence from existing SLRs and MAs (referred as “reviews” in the text) of primary observational studies. As PA is beneficial for health of people of any age, we did not restrict the overview to a particular age group. Additionally, we assessed the overall results of the retrieved reviews in terms of the importance of the determinant, the strength of the evidence and the methodological quality of the reviews.

Methods
This umbrella review is part of the “Determinants of Diet and Physical Activity” (DEDIPAC) project (https://www.dedipac.eu/), which was planned to include seven umbrella reviews on determinants of PA (biological, psychological, behavioral, physical, socio-cultural, economic and policy). The current umbrella review focuses solely on the biological determinants of PA.

We drafted this manuscript following the PRISMA checklist [12]. The protocol of the umbrella systematic review is registered on PROSPERO (Record ID: CRD42015010616), the international prospective register of systematic reviews [13].

**Search strategy and eligibility criteria**

We used the same search strategy for all the seven umbrella reviews, extracting at the end only the articles that included biological determinants. We systematically searched electronic databases for SLRs and MAs investigating the determinants of PA across the life course. An online search was conducted on the following search engines: MEDLINE, ISI Web of Science, Scopus and SPORTDiscus. The search was limited to reviews published in English language from January 2004 to January 2018. In order to summarize the current knowledge on determinants of PA, we did not include the reviews published before 2004. Table 1 shows the MEDLINE search strategy; this was also used as the template for the search strategies in the other databases.

SLRs and MAs of observational primary studies, done on participants at any age, on the association between any determinant and PA, or exercise, or sport as main outcome, were included in the umbrella review. The following were excluded: i) SLRs and MAs of intervention studies; ii) SLRs and MAs that did not focus on the general population (e.g. reviews of studies done on patients, athletes, specific professions); iii) umbrella systematic reviews on the same topic (e.g. reviews of SLRs or MAs of epidemiological studies on determinants associated with PA).
Selection process

Across all databases, our search identified a total number of 18,516 potentially relevant papers. After the removal of duplicates, 15,147 papers remained. Relevant papers were independently screened and assessed by two reviewers belonging to the DEDIPAC KH (Knowledge Hub), who screened the titles and if necessary, the abstracts, and the full texts. Before the final study inclusion or exclusion, a common decision was reached for each study. Any uncertainty and disagreement was resolved by consulting three further authors (SB, LC, AP).

As summarized in Figure 1, after title and abstract reading, 12,414 and 2,198 articles were respectively excluded because they did not meet the inclusion criteria. Thus, a total number of 535 full-text articles were assessed for eligibility, which resulted in inclusion of 63 eligible papers. Of these, 44 reviews did not concern biological determinants of PA. Therefore, the final number of reviews included in the present umbrella review on biological determinants of PA was 19.

Data extraction

For each included review we extracted data on predefined extraction forms, developed by the two authors (KA, AP) and verified by the DEDIPAC KH, which include the following information: year of publication, type of review (SLR or MA), number of eligible primary studies included over the total number of studies included in each review; continent/s of the included studies, primary study design, overall sample size, age range or mean age, sex proportion, year of publication range of included studies; outcome details, type of determinant/s, aim of the review; overall results (qualitative or quantitative), overall recommendations and limitations as provided by the review itself.

Evaluation of importance of determinants and strength of the evidence
We summarized the retrieved results from the eligible studies combining two grading scales, used previously by Sleddens et al [14]. One of the scales grades the importance of the determinants (referring to the consistency of the associations among reviews/individual studies) and the other grades the strength of evidence (referring to the study design used among individual studies).

According to the scale for the importance, a determinant can score a (--) if all reviews, without exception report no association between the determinant and the outcome, a (-) if the association was found in less than 25% of the reviews or of the original studies, and a (0) if the results are mixed, or more specifically, that the variable has been found to be a determinant and/or reported a (non)-significant effect size larger than 0.30 in 25% to 75% of the available reviews or of the primary studies analyzed in these reviews. Furthermore, the importance of the determinant scores a (+) if the association was found in more than 75% of the reviews or of the included individual studies and a (+++) if association was found in all reviews, without exception.

The strength of the evidence is described as “convincing” (Convincing evidence, Ce) if it is based on studies that show consistent associations and have longitudinal design with sufficient size and duration, whereas evidence of “probable” association (Probable evidence, Pe) can be given to determinants showing fairly consistent associations based upon at least two cohort studies. In the second case, there are some shortcomings either in terms of the consistency of the results or other aspects such as limited duration of the studies, small sample sizes or inadequate follow up. Furthermore, “limited suggestive evidence” (Ls) is given to determinants for which there is insufficient number of longitudinal studies and “limited, no conclusive evidence” (Lns) when the evidence for the associations between a determinant and the outcome are based solely on studies of cross-sectional design. [14]
Quality assessment

We assessed the methodological quality of the included reviews using a modified version of the AMSTAR Checklist [15]. The question number 11 referring to the presence of any conflict of interest was modified after a consensus between the DEDIPAC KH partners, so that the conflict of interest was evaluated in the reviews included and not in the primary studies included in each review.

The included SLRs and MAs were independently evaluated by two reviewers belonging to the DEDIPAC KH. Any uncertainty and disagreement was resolved by consulting three further authors (SB, LC, AP). The eleven criteria were evaluated and scored as a 1 when the criterion was applicable to the analyzed review or as a 0 when the criterion was not applicable to the analyzed review. As a consequence, the total quality score for each included review ranged from zero to 11. The quality of the review was labeled as weak (score ranging from 0-3), moderate (score ranging from 4-7), or strong (score ranging from 8-11).

Results

Characteristics of the SLRs and MAs included

The characteristics of the 19 included SLRs and MAs (14 and five respectively) are summarized in Table 2. Since some of them included primary studies that examined the associations between non-biological determinants and PA, we did not appraise all the primary studies included in the individual SLRs or MAs in our umbrella review.

Most of the reviews included primary studies from multiple continents, mostly Europe (14 reviews), North America (13 reviews) and Australia (8 reviews). One review included cohort studies conducted only in Europe [16]. In 11 of the included reviews most of the primary studies were cross-sectional (16,17,18–25,26,27), but there was also a considerable number of
reviews that included prospective and cohort studies [16,18,32,20–22,24,26,29–31]. In six reviews, it was not possible to retrieve the total population sample size of the included studies [17–20,33,34], and two reviews provided only the sum of the individual studies’ sample-sizes [23,30]. In the remaining studies, the total population sample size ranged from 878 to 522,967. Some reviews did not report the age of the participants in the primary studies [24,34]. Finally, the percentage of the female participants, if reported, ranged from zero to 100% of the total sample-size, though these data were absent in some studies [17–20,28,33,34] (Table 2).

Investigated determinants of the reviews

Table 3 summarizes the findings of the included reviews on the associations between the biological determinants of PA. The most frequently studied determinants were age (n=13) [17,18,29,30,33,19–23,25,26,28], sex (n=14) [17,18,29,30,33,34,19–21,23–26,28] and ethnicity (n=10) [17–21,24,29,30,33,34]. BMI or overweight were assessed in nine reviews [17,19–22,25,28,29,33]; two reviews included the family risk in their investigations [18,21], five reviews examined the health status of the participants [21,22,25,27,33], and six reviews investigated physical fitness levels/motor function/motor skills/energy levels as determinants of PA [17–19,21,22,27]. Furthermore, birth weight was studied in three reviews [16,18,32], and anthropometry or body shape/waist circumference in two [18,30]. Finally, two reviews included maturation/level of development in adolescents [17,30], one special educational needs as determinants of PA [17], and one included early growth and motor development [32].

Measurement methods of PA

The majority of the eligible original studies used non-objective measurement methods of PA assessment (e.g. self-reporting, attendance reports) [16,17,27,29–34,19–26]. Objective measurements of PA, assessed by either accelerometer or pedometer, were used in 87 of the eligible original studies, included in nine of the included reviews [17,19–21,24,29–31,33]. One
review did not report the exact number of the studies that used objective and non-objective measures [18].

Evaluation of the quality of the SLRs and MAs

The results of the quality assessment are reported in Table 4. Among the 19 included reviews, 13 were of moderate quality, two reviews were evaluated as weak [20,23] and four as strong [15,31,28,32]. From those reviews that were of moderate quality, 9 [17–19,21,22,25,26,31,34] were scored with four points and four [24,27,29,30] received a quality rating of either six or seven. The characteristics of the included studies were provided by the majority of the reviews (16 out of 19 reviews); however, only five out of 19 reviews provided the list of the included and excluded studies. Furthermore, only four out of 19 reviews used the status of publication as an inclusion criterion and two out of 19 assessed the probability of publication bias.

Summary of the results of the included reviews by importance of determinants and strength of evidence

Table 5 summarizes the results of the associations between the investigated biological determinants and PA, stratified in different age groups.

Pre-School and Older Children

Among pre-school children and older children, for most of the determinants, the reviews reported mixed findings (0, (importance of determinant), Ls (strength of evidence), Table 5). However, among pre-school children, family risk, pre-term birth [18,21] and low health status [21] were negatively correlated to overall PA and/or reported an effect size larger than 0.30 in more than 75% of the identified reviews assessing these two categories of determinants (+, Ls, Table 5). The results were based on studies that were mainly cross-sectional in design. Similarly, being female [18] and lower physical fitness levels [18] are negatively related to...
moderate vigorous PA (MVPA) among pre-school children. These findings are based on studies of both cross-sectional and cohort study design showing fairly consistent associations (+, Pe, Table 5). BMI [21], birth weight [18] based on probable evidence (coded as (-, Pe) in Table 5) and anthropometry/body shape [18], based on limited, suggestive evidence (-, Ls, Table 5) were found to have no association with overall PA in pre-school children.

**Adolescents**

In the adolescents group increasing age and females [20,29–31] were found to be negatively associated with PA. Because of the mixed and contradictory results in part of the studies, these associations are probable (+,Pe, Table 5). No association between body shape and PA among adolescents, (-,Pe, Table 5) was found in one review [30].

**Children and Adolescents**

Among the reviews that included children and adolescents together [17,20,28–30], age was found to be associated with PA (0,Ls), while sex was associated with PA (+,Ls). Birth weight [18,32] was found not to be associated with PA with convincing strength of evidence (--,Ce) (Table 5).

**Adults**

Rural women were a particular adult category investigated by one review only [22]. It emerged that among these women, increasing age and BMI with limited, suggestive levels of evidence (+,Ls and ++, Ls, Table 5), and lower health status and physical fitness levels with a probable level of evidence (++, Pe, and +, Pe, Table 5) respectively are negatively associated to PA.

When adults aged over 18 years were considered together, normal birth was found with convincing strength of evidence to be positively associated to PA and/or reported a significant effect size larger than 0.30 in all identified eligible studies included in the sole review assessing this particular category [16] (+, Ce, Table 5). Additionally, younger age [22,23,25], Caucasian ethnicity [24], better health status [22,27,35], and higher physical fitness levels [22,27] were
again found to be consistently positively associated to PA with a probable level of evidence among adults over 18 years of age (++, Pe, Table 5) and males [23–26] were found to be positively associated to PA in more than 75% of the included studies in the reviews (+, Pe, Table 5).

**Discussion**

The aim of this umbrella systematic review was to summarize the evidence that has been produced to date about the biological determinants of PA across the life course. For most of the determinants, the strength of the level of evidence of the association with PA is mixed or probable. Few of the investigated determinants had convincing strength of evidence (Ce), either because of the lack of consistency of the results between the included studies or because of the small number of cohort studies investigating the specific determinants.

Determinants that were studied most frequently among all ages and demonstrated evidence suggesting a positive association to PA were younger age, being male, higher health status and higher physical fitness levels.

Being female was negatively associated to PA participation in children, adolescents and adults. The included reviews suggest that starting from adolescence and later, in adult life, increasing age is negatively associated to PA. Many reasons may explain these trends and greater understanding of the influence of additional contextual factors is required for both the sex and age determinants.

Apart from a biological background that could explain the avoidance of PA among older adults because of reduced physical capacity for everyday activities [33], other factors that change with age, such as social or behavioral, family, work status or lifestyle, may have influence at different periods of life [36]. The observed sex difference in PA participation also may have socio-cultural background. It is hypothesized that in women and adolescent girls, discouraging family/social environments could determine the observed sex-related differences in PA
participation [37,38]. Our findings are in line with the most recent survey on PA in the citizens of the European Union [36], which indicates steady decrease in PA participation advancing after 24 years of age and lower PA levels in females.

Among pre-school children and older children the results were mixed, with exception of the negative association between being female and MVPA among pre-school children. The reasons behind these mixed results, as reported by the reviews are: small sample sizes, high diversity of the population included between studies and the diversity of the measurement methods of PA used among the primary studies [18,21].

Lower physical fitness levels and health status among adults were consistently found to be negatively associated to PA and reported as barriers to participation in PA [22,25,27,33]. In contrary, PA is considered to have an important role in maintaining and improving the health status [39] indicating that special programmes targeting this particular group could be beneficial.

Normal birth weight was the only determinant for which there was convincing strength of evidence of positive association with PA among adults. This evidence is based on one MA of cohort studies that included adolescents and adults [16]. However, these results should be interpreted with caution because the quality of the individual studies included in this MA was not assessed and it included only population from the Nordic countries in Europe. Contrary to this review, two other MA and SLR that investigated the association of birth weight and PA among children and adolescents [18,32] found no association. Although Andersen et al. [16] included adolescents in their study, they did not analyse the data in a way to assess the association specifically for this age group. However, the age stratification between younger and older than 35 years showed lower association between birth weight and PA in the younger participants’ group [16]. According to the above mentioned reviews [16,18,32], normal birth weight was positively associated to PA only among adults. It is proposed that the rapid infant
growth among those with lower birth weight may lead to adiposity later in life, which has
negative impact on PA [32]. Based on these three reviews it can be proposed that the normal
birth weight might be positively correlated to PA among adults only.

Ethnicity was commonly studied as a determinant but, except for the adults >18 years, the
results were usually mixed or insufficient to make final conclusions. The investigated ethnic
groups differ among studies and reviews, which may contribute to the inconsistency of results.
Also, since many reviews compared immigrants and ethnic minorities with the general
population of the countries [17,18,40,19–21,24,29,30,33,34], there is a possibility of bias by
socio-economic status that was not controlled in all of the individual studies.

BMI was another determinant with insufficient evidence among all age groups, due to mixed
results among studies or lack of studies of longitudinal design that considered this determinant.
A recent cohort study of older children showed that increased adiposity is associated to
reduction of PA [41], but as yet no SLR/MA confirmed that.

Family risk for obesity and cardiovascular diseases was found to be negatively associated with
PA among pre-school children, but the strength of evidence is insufficient [18,21]. The same
strength of evidence was found for most of the determinants investigated among children and
adolescents, due to the large variation in the determinants investigated in different studies,
which meant few could be compared, and the abundance of cross-sectional studies and lack of
longitudinal investigations.

The majority of the studies included in the reviews were done in continents that include more
developed countries. As a consequence, some determinants that may be characteristic and more
relevant among less developed countries may not be shown.

Additionally, most of the included reviews were of moderate methodological quality. Most of
them did not include grey literature and the probability of publication bias was rarely assessed.
Additionally, half of the reviews did not assess the methodological quality of the studies and did not provide list of excluded studies.

Additionally, PA was almost always assessed only in general terms (overall PA), rather than specific types of activity (e.g. leisure time, house activity, active travel) and was not defined clearly and uniformly among studies [16,17,31,33,34,20,22–26,28,30]. PA may have different patterns among sex, age or socio-cultural contexts, which creates possibility of bias when comparing the amount of PA between populations. Also, the lack of unified measurement methods of PA is an additional problem that was encountered among all the reviews. Specific definitions of PA may reveal greater insights into the determinants of PA behaviour and together with a standardization of the assessment methods would enable a greater comparability among studies.

In addition, future studies on the mechanisms that underlie the proposed associations are needed in order to improve the knowledge about the biological determinants that influence PA.

**Conclusions**

Despite the limitations, there are still recommendations that can be drawn from this umbrella review. Age, sex, birth weight, health status and physical fitness levels should be taken into consideration when introducing interventions aimed at increasing PA. Age, sex and birth weight are non-modifiable factors, but special attention should be given to the possible social and behavioural interactions that may cause the observed associations. Creating programmes targeted at diverse ages, female population and people with non-normal birth weight can be helpful. In addition, since poor health status and lower physical fitness levels were often found as a barrier to participating in PA, it is recommended to adopt separate interventions according to the individual’s capacity for PA.
Abbreviations

WHO: World Health Organization

PA: Physical activity

NCDs: Non-communicable diseases

BMI: Body Mass Index

SLRs: Systematic literature reviews

MAs: Meta-analyses

DEDIPAC: Determinants of Diet and Physical Activity

KH: Knowledge Hub

Ce: Convincing evidence

Pe: Probable evidence

Ls: Limited suggestive evidence

Lns: Limited, no conclusive evidence
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Management team for their helpful support.
References


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Figure 1 title: Flowchart of the literature research by database.

Figure 1 legend: Notes: MA: meta-analysis; SLR: systematic literature review

Table 1. Search strategy: key words used for the literature research.

<table>
<thead>
<tr>
<th>Set</th>
<th>Search terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>“physical activit*” OR “physical exercise*” OR sport OR “motor activit*” OR “locomotor activit*” OR athletic* OR fitness OR “physical movement*” OR “physical performance*” OR “aerobic exercise*” OR “physical effort*” OR “physical exertion*”</td>
</tr>
<tr>
<td>#2</td>
<td>determinant OR determinants OR correlator OR correlators OR mediator OR mediators OR moderator OR moderators OR contributor OR contributors OR factor OR factors OR association OR modifier OR modifiers OR confounder OR confounders OR pattern OR patterns OR predictor*</td>
</tr>
<tr>
<td>#3</td>
<td>demographic* OR motivation OR cognition OR emotion* OR attitude* OR “self-perception” OR “self-confidence” OR “self-efficacy” OR competence OR reward* OR success* OR challenge* OR knowledge OR belief* OR “personal trait*” OR “body image” OR satisfaction OR “time availability” OR “perceived environment” OR family OR peer* OR school* OR leader* OR coach* OR group* OR “climate” OR network* OR employment OR retirement OR “educational level” OR SES OR “socioeconomic status” OR “local identity” OR “national identity” OR value* OR tradition* OR “social expectation*” OR “social trend*” OR “social barrier*” OR “availability of tool*” OR “availability of service*” OR “access to tool*” OR “access to service*” OR neighborhood OR “community route*” OR “school environment” OR “work environment” OR architecture OR urbanization OR transport OR traffic OR “facilit* in public space*” OR advertisement OR “availability of sport club*” OR “availability of fitness center*” OR advocacy OR lobbying OR “corporate social responsibility” OR “physical activity promotion initiative*” OR legislation OR health OR education OR tourism OR environment OR “urban planning” OR transport* OR sport OR sports OR culture OR dance OR theater OR “gender mainstreaming” OR “social inclusion” OR “fiscal measure*” OR program* OR plan OR plans OR communication OR media OR guideline*</td>
</tr>
<tr>
<td>#4</td>
<td>“systematic literature review” OR “meta-analysis”</td>
</tr>
<tr>
<td>Study/type of review</td>
<td>Number of individual studies included in the umbrella review</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------------------------------------------------</td>
</tr>
<tr>
<td>Barnett et al. (MA) [28]</td>
<td>50/59</td>
</tr>
<tr>
<td>Ogland et al. (MA) [32]</td>
<td>11/11</td>
</tr>
<tr>
<td>Olsen et al. (SLR) [22]</td>
<td>13/21</td>
</tr>
<tr>
<td>Barnett et al. (SLR) [34]</td>
<td>38/38</td>
</tr>
<tr>
<td>Ogen et al.</td>
<td>11/11</td>
</tr>
<tr>
<td>Babakus et al. (SLR) [24]</td>
<td>5/5</td>
</tr>
<tr>
<td>Hinkley et al. (SLR) [21]</td>
<td>20/24</td>
</tr>
<tr>
<td>Tzormpatzakis et al. (SLR) [23]</td>
<td>36</td>
</tr>
<tr>
<td>Van der Horst et al. (SLR) [20]</td>
<td>30/60</td>
</tr>
<tr>
<td>Rhode et al. (SLR) [26]</td>
<td>15/35</td>
</tr>
</tbody>
</table>

Notes: MA: meta-analysis; SLR: systematic literature review; N.A.= not available from the review; *included studies are the original studies that assessed biological determinants.
Table 3. Results of the included reviews

<table>
<thead>
<tr>
<th>Study type of review</th>
<th>Outcome(s)</th>
<th>Determinant(s)</th>
<th>Review aim</th>
<th>Overall qualitative results of the review</th>
<th>Overall quantitative results of the review</th>
<th>Overall limitations of the study</th>
<th>Overall recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnett et al. (MA)[28]</td>
<td>Object control movement skill competency, locomotor skill competency, stability, motor coordination, skill components</td>
<td>Age, sex, BMI</td>
<td>To identify factors correlated with motor competency</td>
<td>Age is positively correlated with physical activity, while adiposity is negatively. Boys are more skilled than girls for object control and motor coordination.</td>
<td>Correlation coefficient for age: 0.17, 95% CI 0.20-0.45; 0.45, 95% CI 0.36-0.53; 0.34, 95% CI 0.29-0.39</td>
<td>Few studies focused on the same correlate and the same motor skill outcome. Few studies provided correlation coefficients.</td>
<td>Additional research that investigates the role of many correlates of motor competency.</td>
</tr>
<tr>
<td>Ogland et al. (MA)[32]</td>
<td>Overall PA, motor development, early growth</td>
<td>Birth weight, motor development, early growth</td>
<td>To explore whether birth weight, early growth and motor development act as determinants of physical activity in children and youth</td>
<td>Birth weight is not an important determinant of physical activity in youth. Available data do not allow firm conclusions whether early growth and motor development act as determinants of physical activity in youth.</td>
<td>b=-3.08, 95% CI -10.20, 4.04</td>
<td>Several of the studies had limitations impacting the quality of the results, but these were not necessarily captured in the standardized quality assessment.</td>
<td>More data from high quality birth-cohort studies are warranted before firm conclusions can be made.</td>
</tr>
<tr>
<td>Olsen et al. (SLR)[22]</td>
<td>PA behaviour</td>
<td>Health, age, lack of energy, weight</td>
<td>To identify factors that influence PA in rural women</td>
<td>Rural women were found to be less active and experience more barriers to PA than urban women. PA determinants among rural women can be categorized according to personal, socio-economic, and physical environment factors.</td>
<td>N.A.</td>
<td></td>
<td>Additional research that clearly defines and consistently applies the terms rural and PA is needed to strengthen knowledge in this area.</td>
</tr>
<tr>
<td>Babakus et al. (SLR)[24]</td>
<td>Mixture of PA (total, leisure time, home work, active commuting, energy expenditure, occupational, intensity, steps or physical inactivity) and sitting time</td>
<td>Sex, ethnicity</td>
<td>To assess what is known about the levels of PA and sedentary time and to contextualize these behaviors among South Asian women with an immigrant background</td>
<td>South Asian women were less active than the other ethnic groups as well as compared to South Asian males.</td>
<td>N.A.</td>
<td></td>
<td>More research should be dedicated to standardize objective PA measurement and to understand how to utilize the resources of the individuals and communities to increase PA levels and overall health of South Asian women.</td>
</tr>
<tr>
<td>Barnett et al. (SLR)[34]</td>
<td>PA change across transition to retirement (secondary: leisure time PA, structured exercise, total PA)</td>
<td>Sex, ethnicity</td>
<td>To gain a deeper understanding of qualitative evidence on PA around the transition to retirement</td>
<td>Overall, exercise and leisure-time PA increased after the transition to retirement, whereas the findings regarding changes in total PA were inconclusive, men tend to be more active than women</td>
<td>N.A.</td>
<td>Limited number of studies with population from limited socioeconomic diversity; different approaches to assess PA between studies.</td>
<td>More research should address predictors of maintenance of recreational PA after the transition to retirement, the broader benefits of PA, and barriers to PA among ethnics from lower occupational groups.</td>
</tr>
<tr>
<td>De Craemer et al. (SLR)[18]</td>
<td>Overall PA, MVPA, active transport, during recess</td>
<td>Sex, family risk, preterm birth, birth weight, age, ethnicity, waist circumference, movement skills</td>
<td>To systematically review the correlates of PA, sedentary and active behaviour in preschool children 4-6 years old</td>
<td>Little support for biological correlates and PA in general; strong correlation with sex and age; PA, negative association with family obesity risk and positive correlation with gestational age</td>
<td>N.A.</td>
<td>Some limitations regarding the coding of the association of the variables; several studies included wider age range.</td>
<td>Strategies should target both boys and girls, all ethnic groups, and parents of both low and high SES, especially on weekdays, should be a focus on maintaining the level of PA and decreasing the level of sedentary behaviour; on weekends, the focus should be on increasing the level of PA.</td>
</tr>
<tr>
<td>Ridgers et al. (SLR)[17]</td>
<td>Recess PA</td>
<td>Age, sex, BMI, overweight, body mass, maintenance, motor control, fitness, special educational needs</td>
<td>To examine the correlation of children’s and adolescent’s PA during school recess periods</td>
<td>Boys are more physically active during recess, no association was found for BMI, central adiposity and grade level.</td>
<td>N.A.</td>
<td>The majority are small-sized and cross-sectional studies. MA is difficult to obtain given the limited number of studies and the lack of consistency between them, lack of objective measures.</td>
<td>More research is needed concerning correlates of PA in recess period, particularly in adolescents, schools to increase overall facility provision, unfurl equipment and methods to increase social support, particularly by peers.</td>
</tr>
</tbody>
</table>
Table 3 (continued)

<table>
<thead>
<tr>
<th>Authors/Year</th>
<th>Study Design</th>
<th>Methods/Outcome Measures</th>
<th>Key Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stanley et al. (SLR)[19]</td>
<td>School break time PA, cross-sectional studies</td>
<td>Age, sex, motor skills, BMI, ethnicity</td>
<td>To identify the correlates of childhood PA (8-14 years) occurring during the school break-time and after school periods. Boys and younger children tended to be more active during break-time and after school. BMI in females was negatively associated with after-school PA. Age was negatively associated in school-break and after school. Small number of studies that vary in methodological aspects; possibility that some studies are missed during the search process; majority of cross-sectional studies.</td>
</tr>
<tr>
<td>Uijtdewilingen et al. (SLR)[29]</td>
<td>Overall PA</td>
<td>Age, sex, ethnicity, BMI, anthropometry</td>
<td>To summarize and update the existing literature on determinants of PA and sedentary behaviour in young people. Moderate evidence of positive relationship between age PA and negative relationship between ethnicity and PA among adolescents.</td>
</tr>
<tr>
<td>Craggs et al. (SLR)[30]</td>
<td>Overall PA</td>
<td>Sex, anthropometry, ethnicity, age, developmental state,</td>
<td>To systematically review the published evidence regarding determinants of change in PA in children and adolescents. Inconclusive associations were reported for large proportion of the determinants examined.</td>
</tr>
<tr>
<td>Dumith et al. (MA)[31]</td>
<td>Overall PA</td>
<td>Age</td>
<td>To systematically review the international literature regarding PA change in adolescence and quantity that change. The decline in PA during adolescence is consistent finding among studies. In the later studies the decline is more prominent among girls than in boys, although these differences are not significant. Lack of methodological evaluation of the studies included; some studies may be missed in the search process; the original estimate of PA change variability (e.g. standard error) of each study should be preferable to the meta-regression analyses, rather than the used estimate based on the sample size.</td>
</tr>
<tr>
<td>Koeneman et al. (SLR)[33]</td>
<td>Overall PA, overall ex, overall PA/ex</td>
<td>Sex, age, ethnicity, chronic conditions/disease, general physical health, BMI</td>
<td>To systematically review determinants of PA and exercise among healthy older adults. The heterogeneity of the studies allowed only moderate conclusions. There may be possibility of publication bias; a wide age range is applied that might have masked some of the differences between subsamples inside that population; they included some specific subsamples of the older population; overall low quality of the studies included.</td>
</tr>
<tr>
<td>Siddiqi et al. (SLR)[27]</td>
<td>Overall PA</td>
<td>Physical disability/disease, fatigue, body shape/physical appearance</td>
<td>To systematically review the qualitative literature pertaining to impediments and enablers of PA participation among African Americans. Primary biological determinants influencing PA were fatigue and processing chronic diseases. Possibility of publication bias; many included studies included only women.</td>
</tr>
<tr>
<td>Authors</td>
<td>Type</td>
<td>Variable(s)</td>
<td>Method</td>
</tr>
<tr>
<td>------------------</td>
<td>------</td>
<td>------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Andersen et al.</td>
<td>MA</td>
<td>Active vs. inactive</td>
<td>Birth weight</td>
</tr>
<tr>
<td>Hinkley et al.</td>
<td>SLR</td>
<td>Overall PA</td>
<td>Age, sex</td>
</tr>
<tr>
<td>Teompinotakis et al.</td>
<td>SLR</td>
<td>Total PA, leisure time PA, occupational PA, exercise</td>
<td>Sex, age</td>
</tr>
<tr>
<td>Van der Horst et al.</td>
<td>SLR</td>
<td>Overall PA</td>
<td>Age, sex, ethnicity</td>
</tr>
<tr>
<td>Coble et al.</td>
<td>SLR</td>
<td>Overall PA</td>
<td>Age, sex, body weight, health status</td>
</tr>
<tr>
<td>Rhodes et al.</td>
<td>MA</td>
<td>Overall PA</td>
<td>Sex, age</td>
</tr>
</tbody>
</table>

Notes: BMI: body mass index; CVD: cardiovascular disease; ERS: exercise referral schemes; MA: meta-analysis; SLR: systematic literature review; MVPA: moderate to vigorous physical activity; LTPA: leisure-time physical activity; OR: odds ratio; CI: confidence interval; PA: physical activity; SES: socio-economic status.
### Table 4. Quality assessment of the included reviews using the AMSTAR Checklist [15].

<table>
<thead>
<tr>
<th>Study</th>
<th>Was an 'a priori' design provided?</th>
<th>Was there duplicate study selection and data extraction?</th>
<th>Was a comprehensive literature search performed?</th>
<th>Was the status of publication (i.e., grey literature) used as an inclusion criterion?</th>
<th>Was a list of studies (included and excluded) provided?</th>
<th>Were the characteristics of the included studies provided?</th>
<th>Was the scientific quality of the included studies assessed and documented?</th>
<th>Was the scientific quality of the included studies used appropriately in formulating conclusions?</th>
<th>Were the methods used to combine the findings of studies appropriate?</th>
<th>Was the likelihood of publication bias assessed?</th>
<th>Was the conflict of interest included?</th>
<th>Sum quality score</th>
<th>Quality of the review</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnett et al. [28]</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>9</td>
<td>Strong</td>
</tr>
<tr>
<td>Oglund et al. [32]</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>8</td>
<td>Strong</td>
</tr>
<tr>
<td>Olsen et al. [22]</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N.A.</td>
<td>C.A.</td>
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</tr>
<tr>
<td>Babakus et al. [24]</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N.A.</td>
<td>No</td>
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<td>Moderate</td>
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<tr>
<td>Barnett et al. [34]</td>
<td>Yes</td>
<td>No</td>
<td>C.A</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N.A.</td>
<td>No</td>
<td>4</td>
<td>Moderate</td>
</tr>
<tr>
<td>De Craemer et al. [18]</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>N.A.</td>
<td>Yes</td>
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<tr>
<td>Ridgers et al. [17]</td>
<td>Yes</td>
<td>C.A</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N.A.</td>
<td>N.A.</td>
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<tr>
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<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>N.A.</td>
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</tr>
<tr>
<td>Uijtdewilligen et al. [29]</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>N.A.</td>
<td>N.A.</td>
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</tr>
<tr>
<td>Cragg et al. [30]</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>6</td>
<td>Moderate</td>
</tr>
<tr>
<td>Damith et al. [31]</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N.A.</td>
<td>No</td>
<td>4</td>
<td>Moderate</td>
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<tr>
<td>Koersman et al. [33]</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>N.A.</td>
<td>No</td>
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<tr>
<td>Siddiqi et al. [27]</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Andersen et al. [16]</td>
<td>Yes</td>
<td>N.A.</td>
<td>Yes</td>
<td>Yes</td>
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<td>No</td>
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<td>Yes</td>
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<td>Yes</td>
<td>8</td>
<td>Strong</td>
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<tr>
<td>Hinkley et al. [21]</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N.A.</td>
<td>No</td>
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<tr>
<td>Tzompapatziakos et al. [23]</td>
<td>No</td>
<td>C.A</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>N.A.</td>
<td>No</td>
<td>2</td>
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</tr>
<tr>
<td>Van der Horst et al. [20]</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>N.A.</td>
<td>No</td>
<td>3</td>
<td>Weak</td>
</tr>
<tr>
<td>Coble et al. [25]</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>4</td>
<td>Moderate</td>
</tr>
<tr>
<td>Rhodes et al. [26]</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N.A.</td>
<td>No</td>
<td>4</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

Notes: C.A.: Cannot answer; N.A.: Not applicable.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>When the criteria were not applicable for the included review.</td>
</tr>
<tr>
<td>1</td>
<td>When the criteria were applicable for the included review.</td>
</tr>
<tr>
<td>Weak</td>
<td>(score ranging from 0-3); moderate (score ranging from 4-7); strong (score ranging from 8-11). [15]</td>
</tr>
</tbody>
</table>
Table 5. Summary of the results of the included reviews: the importance of a determinant and its strength of evidence.

<table>
<thead>
<tr>
<th>Determinant</th>
<th>Children and adolescents (overall PA)</th>
<th>Preschool children (overall PA)</th>
<th>Preschool children (MVPA)</th>
<th>Children</th>
<th>Adolescents</th>
<th>Adults &gt;40 (overall PA)</th>
<th>Adults &gt;40 (overall ex)</th>
<th>Adults &gt;40 (overall ex/PA)</th>
<th>Adults &lt;40</th>
<th>All ages (&gt;18)</th>
<th>Rural women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maturation</td>
<td>0, Ls [16, 30]</td>
<td>0, Ls [17, 30]</td>
<td>0, Ls [17, 30]</td>
<td>0, Ls [17, 30]</td>
<td>0, Ls [17, 30]</td>
<td>0, Ls [17, 30]</td>
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<td>Early growth</td>
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</table>

Notes: Ce: Convincing evidence; Lns: Limited, no conclusive evidence; Ls: Limited, suggestive evidence; Pe: probable evidence; BMI: body mass index; Ex: exercise; PA: physical activity; MVPA: moderate to vigorous physical activity; --: all reviews report no association between the determinant and the outcome; -: association found in less than 25% of the reviews or of the original studies; 0: the variable has been found to be a determinant and/or reported a (non)-significant effect size larger than 0.30 in 25% to 75% of the available reviews or of the primary studies analyzed in these reviews; +: association found in more than 75% of the reviews or of the included individual studies; ++: association found in all reviews.