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Daily step count and cardiometabolic risk in young people: a systematic review

Número de passos por dia e risco cardiometabólico em jovens: revisão sistemática

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Abstract – The aim of this systematic review was to analyze the association between the number of daily steps and cardiometabolic risk factors in children and adolescents. Studies published from 1 January 2000 to 31 May 2016 in the PubMed, SciELO and LILACS databases were analyzed. Manual searches of the reference lists of the selected articles were also performed. Of the 4,454 articles retrieved, eight studies met the eligibility criteria and were included in the analysis. Seven of these studies reported some significant association between step count and cardiometabolic risk factors. However, the data suggested the lack of an association with hyperglycemia, were inconclusive regarding lipid profile alterations, divergent for high blood pressure, and indicated an association with insulin resistance and metabolic syndrome only in males. The findings of this systematic review do not permit to determine the association between step count and cardiometabolic risk factors in young people. The small number of articles that met the eligibility criteria and the different methodological problems of the studies reviewed were the main factors limiting inferences. Observational studies with a longitudinal design (cohort and case-control) and accurate methodological control are necessary.

Key words: Adolescent; Cardiovascular diseases; Child; Motor activity; Review; Risk factors.

Resumo – *O objetivo desta revisão sistemática foi analisar a associação entre o número de passos por dia e fatores de risco cardiometabólico em crianças e adolescentes. Foram analisados estudos publicados de 01 de janeiro de 2000 até 31 de maio de 2016 nas bases de dados PubMed, SciELO e LILACS. Buscas manuais nas listas de referências dos artigos incluídos também foram realizadas. Dos 4.454 registros encontrados, oito estudos atenderam aos critérios de elegibilidade e foram incluídos para análise. Desses, sete observaram alguma associação significativa entre número de passos e fatores de risco cardiometabólico. No entanto, as evidências sugerem ausência de associação com a hiperglicemia, foram inconclusivas para alterações no perfil lipídico, divergentes para pressão arterial elevada e indicaram associação com a resistência a insulina e síndrome metabólica somente para o sexo masculino. Os achados da presente revisão sistemática não permitem determinar a associação entre o número de passos e fatores de risco cardiometabólico em jovens. O reduzido número de artigos que atenderam aos critérios de elegibilidade e os diversos problemas metodológicos dos estudos revisados foram os principais fatores que limitaram maiores inferências. Investigações observacionais com delineamento longitudinal (coorte e caso-controle) e com acurado controle metodológico são necessárias.*

Palavras-chave: *Adolescente; Atividade motora; Criança; Doenças cardiovasculares; Fatores de risco; Revisão.*

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INTRODUCTION

Cardiovascular and metabolic diseases are the main causes of morbidity and mortality worldwide[1]. Classical cardiometabolic risk factors such as high blood pressure, glucose and total cholesterol account for more than 15% of disability-adjusted life years lost[1]. These risk factors have also been observed in pediatric age groups, with worrisome stability from childhood to adulthood[2,3].

Evidence suggests that the lack of physical activity, which is considered the fourth leading risk factor for global mortality according to the World Health Organization[4], is associated with an unfavorable cardiometabolic profile in young people[5-8]. However, it should be remembered that physical activity is a complex behavior that comprises the type, duration, frequency and intensity of activities performed over a given period of time[9]. Thus, different associations with cardiometabolic risk factors may be obtained depending on the method used to measure this behavior[5]. In general, more consistent associations with cardiometabolic risk factors are observed in young people when physical activity is estimated objectively rather than self-reported[5].

In recent years, objective monitoring of physical activity has become more common, especially the use of accelerometers and pedometers[9-11]. Accelerometers provide data for a more detailed analysis of the complex patterns of physical activity and of sedentary behavior because of the capacity of these devices to estimate the intensity, frequency and duration of the activity[12]. However, the use of accelerometers in public health services is generally limited because of their high cost, because visualization of the results depends on a computer interface, and because users need to be trained to manipulate the device and to interpret the data[13].

On the other hand, the pedometer provides an estimate of the number of daily steps, an indicator of physical activity that can be easily understood by any individual[10]. Pedometers have additional advantages such as a relative low cost, practicality, and the results are easily obtained and interpreted[10,14]. Additionally, the pedometer has been shown to be a useful tool to encourage the practice and self-monitoring of physical activity in the pediatric population[15]. However, the association between step count and cardiometabolic risk factors in young people still requires further investigation. Most studies, including systematic reviews, that investigated this association used self-report or accelerometers for the measurement of physical activity[5,6,8].

Understanding the association of step count with cardiometabolic risk factors in young people is necessary to define the potential of pedometers as a tool that assists in the early coping with cardiometabolic outcomes. Within this context, we performed a systematic review on the association between step count and cardiometabolic risk factors in children and adolescents.

METHODOLOGICAL PROCEDURES

Design, protocol and registration

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) Statement[16]. In addition, the Cochrane Handbook for Systematic Reviews[17] was consulted during the study. The study protocol was not registered in the International Prospective Register of Systematic Reviews (PROSPERO) database.

Search strategy

Studies published from 1 January 2000 to 31 May 2016 in the PubMed, SciELO and LILACS databases were evaluated. The following search strategy was used in PubMed and the same search terms were used in the other databases: ("physical activity"[All Fields] OR "motor activity"[All Fields] OR "pedometer"[All Fields] OR "pedometry"[All Fields] OR "number of steps"[All Fields] OR "steps/day"[All Fields] OR "step-count"[All Fields]) AND ("blood pressure"[All Fields] OR "hypertension"[All Fields] OR "high blood pressure"[All Fields] OR "glucose"[All Fields] OR "glycemia"[All Fields] OR "hyperglycemia"[All Fields] OR "cholesterol"[All Fields] OR "LDL cholesterol"[All Fields] OR "HDL cholesterol"[All Fields] OR "VLDL cholesterol"[All Fields] OR "dyslipidemia"[All Fields] OR "hypertriglyceridemia"[All Fields] OR "insulin"[All Fields] OR "insulin resistance"[All Fields] OR "insulin sensitivity"[All Fields] OR "cardiovascular risk factors"[All Fields] OR "cardiovascular disorders"[All Fields] OR "cardiovascular risk"[All Fields] OR "metabolic syndrome"[All Fields] OR "metabolic risk"[All Fields] OR "metabolic risk factors"[All Fields] OR "metabolic disorders"[All Fields] OR "cardiometabolic risk"[All Fields] OR "cardiometabolic risk factors"[All Fields] OR "cardiometabolic disorders"[All Fields]) NOT ("Clinical Trial"[All Fields] OR "Controlled Clinical Trial"[All Fields] OR "Randomized Controlled Trial"[All Fields] OR "Review"[All Fields]) AND (("2000/01/01"[PDAT]: "2016/05/31"[PDAT]) AND ("child"[MeSH Terms:noexp] OR "adolescent"[MeSH Terms])). The reference lists of key articles were also checked.

The literature search was conducted by two independent researchers who first screened the titles and abstracts of the articles. Relevant articles were then selected for reading of the full text. Duplicated articles were removed.

Eligibility criteria

The following criteria were adopted for inclusion of the study in the systematic review:

- Investigating the association between the number of steps and cardiometabolic risk factors.

- Reporting data for children and adolescents (age between 6 and 18 years, or part of this age range, or mean age within this age range).
- Observational studies (cross-sectional, cohort, and case-control).
- Reporting the results of association analysis.
- Articles published in Portuguese, English, or Spanish.

Studies whose samples consisted of young people of the general population were selected. Studies involving specific groups of patients with previously diagnosed diseases were not included in the review. The stages of study selection are illustrated in Figure 1.

Extraction of data

The information extracted from the articles selected for this review focused on the following items:

1) Descriptive: study, year of publication, study location, study design, sample size, age group, and sex.
2) Methodological: characteristics of exposure and outcome measurements and statistical analysis used.
3) Description of the main findings.

RESULTS

A total of 4,454 articles were retrieved, including 1,933 from PubMed, 141 from SciELO, 2,000 from LILACS, and 320 from other sources. After exclusion of duplicates and reading of the titles and abstracts, 37 articles remained for full-text reading. After this step, 29 articles were excluded for the following reasons: the study did not evaluate the number of steps as an exposure variable (n=28) or did not use statistical association analysis (n=1). Finally, eight articles were selected for the systematic review (Figure 1).

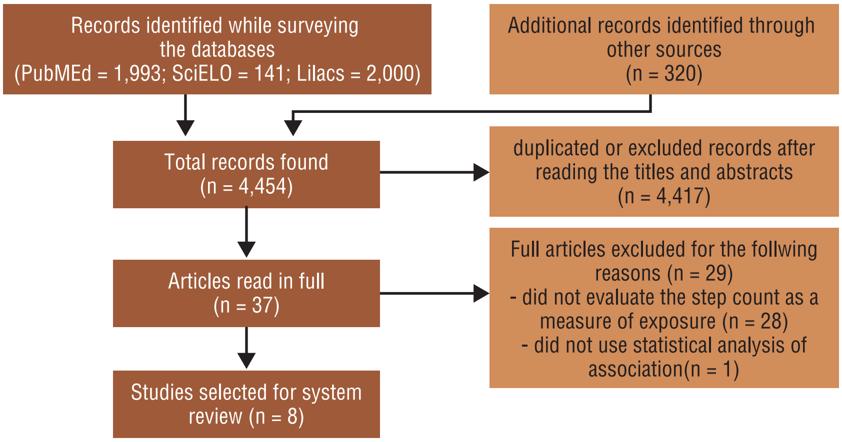

Figure 1. Flow chart of the selection process of articles for the systematic review.

Study location, design and population

Articles published over the last 16 years were analyzed (1 January 2000 to

31 May 2016). The oldest study was published in 2009[18] and the latest in 2016[19]. Four of the eight studies analyzed were conducted in Australia[18,20-22], three in Brazil[19,23,24], and one in Portugal[25]. Five different samples and/or databases were investigated in the eight selected articles, considering that different studies used the same database (*Canberra*, *Australia*[20-22] and Viçosa, Minas Gerais, Brazil[23,24]). Five studies had a cross-sectional design[18,19,23-25] and three were cohort studies[20-22]. Regarding the population studied, seven articles investigated both sexes[19-25] and one only females[18]. Age ranged from 6 to 18 years in the samples studied. The sample size of the studies ranged from 187[23,24] to 1,139 participants[19] (Table 1).

Exposure, outcome and statistical analysis

Five different pedometer brands and/or models were used. In seven studies, the pedometer was used by young people for seven days[19-25] and in one study for four days[18]. The following cardiometabolic outcomes were investigated: high blood pressure (three studies), insulin resistance (two studies), metabolic syndrome (two studies), hyperglycemia (one study), lipid profile (one study), dyslipidemia (one study), hypertriglyceridemia (one study), low HDL-cholesterol (one study), and presence of one or more clustered cardiometabolic risk factors (one study). Regarding statistical treatment, a generalized linear mixed model was used in three studies, logistic regression and ROC curves in two studies, and Poisson regression in one study (Table 1).

Main findings

Seven studies observed some significant association between step count and cardiometabolic risk factors[19-25]. However, in most studies the associations were not significant for either sex or different outcomes (Table 2).

Three cross-sectional studies investigated high blood pressure as outcome[18,19,24]. Two of these studies found no association between step count and the outcome[18,24]. On the other hand, in the study of Quadros et al.[19], young people with a larger number of daily steps were less likely to develop high blood pressure.

The two studies in which insulin resistance was the outcome were longitudinal studies that used the same database for analysis[20,21]. In one study, the participants were followed up from 8 to 10 years of age[20] and in the other from 8 to 12 years[21]. In both studies, variations in the number of steps explained changes in insulin resistance only in boys.

Metabolic syndrome was investigated as outcome in two cross-sectional studies that used the same database for analysis[23,24]. As observed for insulin resistance, step count was only associated with metabolic syndrome in boys.

The only study investigating hyperglycemia as outcome was a cross-sectional study that reported no association with step count[19]. On the other hand, the only study, also cross-sectional, that investigated the presence of one or more clustered cardiometabolic risk factors found an association with step count[25].

Table 1. Description of the selected studies on the association of step count with cardiometabolic risk factor in children and adolescents.

Study	Year of publication	Location	Study design	Population	Evaluation of the number of steps	Cardiometabolic risk factor (outcome)	Statistical analysis
Schofield et al.[18]	2009	Queensland, Australia	Cross-sectional	415 adolescent girls, mean age of 16 years	Monitoring for 4 days with a Yamax Digi-walker SW-700 pedometer	High blood pressure	Logistic regression
Telford et al.[20]	2009	Canberra, Australia	Cohort	498 children (257 girls), follow-up from 8 to 10 years	Monitoring for 7 days with a Walk4Life pedometer	Insulin resistance[a]	Generalized linear mixed model
Moreira et al.[25]	2011	Açores, Portugal	Cross-sectional	417 adolescents (243 girls), age from 15 to 18 years	Monitoring for 7 days with a Kenz Lifecorder Plus pedometer	Presence of one or more of the following cardiometabolic risk factors: abdominal obesity, hyperglycemia, low HDL-cholesterol, hypertriglyceridemia, and high blood pressure	Logistic regression
Telford et al.[21]	2012	Canberra, Australia	Cohort	534 children (278 girls), follow-up from 8 to 12 years	Monitoring for 7 days with a Walk4Life pedometer	Insulin resistance[a]	Generalized linear mixed model
Andaki et al.[24]	2014	Viçosa, Minas Gerais, Brazil	Cross-sectional	187 children (106 girls), mean age of 9.90 years	Monitoring for 7 days with a DX-8897 pedometer	Hypertriglyceridemia, low HDL-cholesterol, high blood pressure, and metabolic syndrome[b]	ROC curve
Andaki et al.[23]	2014	Viçosa, Minas Gerais, Brasil	Cross-sectional	187 children (106 girls), mean age of 9.90 years	Monitoring for 7 days with a DX-8897 pedometer	Metabolic syndrome[b]	ROC curve
Telford et al.[22]	2015	Canberra, Australia	Cohort	469 children (240 girls), follow-up from 8 to 12 years	Monitoring for 7 days with a Walk4Life pedometer	Altered lipid profile	Generalized linear mixed model
Quadros et al.[19]	2016	Amargosa, Bahia, Brazil	Cross-sectional	1,139 children and adolescents (633 girls), age from 6 to 18 years	Monitoring for 7 days with a Yamax Digi-walker SW-200 pedometer	Dyslipidemia, hyperglycemia, and high blood pressure	Poisson regression

Note. a Insulin resistance evaluated by homeostatic model assessment of insulin resistance (HOMA-IR). b Metabolic syndrome was assessed using the criteria of Ferranti et al.24

Regarding lipid profile, the cross-sectional findings indicated that total cholesterol[22] and HDL-cholesterol[22,24] were associated with step count only in boys. Dyslipidemia was investigated in one study that did not report an association with step count[19]. Two studies investigated hypertriglyceridemia as outcome[22,24] and an association with step count was found in one, but only in boys[22]. According to the only longitudinal study, changes in the number of steps from 8 to 12 years of age did not explain alterations in the lipid profile[22].

DISCUSSION

To our knowledge, this is the first systematic review that investigated the association between step count and cardiometabolic risk factors in young

Table 2. Main findings of the selected studies on the association of step count with cardiometabolic risk factor in children and adolescents.

Study	Main findings
Schofield et al.[18]	There was no association between step count and high blood pressure.
Telford et al.[20]	In cross-sectional analysis, no significant association was found between step count and insulin resistance in boys or girls, while longitudinal analysis revealed an association only in boys.
Moreira et al.[25]	Adolescents in the 4th quartile of step count were less likely to have one or more metabolic risk factors compared to those in the 1st quartile (OR = 0.56).
Telford et al.[21]	Variations in step count explained changes in insulin resistance only in boys (boys: β = -0.007, p = 0.039; girls: β = 0.0005, p = 0.85).
Andaki et al.[24]	Step count was a predictor of low HDL-cholesterol and metabolic syndrome only in boys (AUC = 0.891 and AUC = 0.817, respectively).
Andaki et al.[23]	Step count was a predictor of metabolic syndrome only in boys (AUC = 0.891).
Telford et al.[22]	There was no evidence of a longitudinal relationship between step count and lipid profile in either sex. In cross-sectional analysis, boys (but not girls) with a larger number of steps had higher HDL-cholesterol and lower triglycerides (p = 0.04 and p = 0.03, respectively).
Quadros et al.[19]	There was an association of step count with high blood pressure (PR = 1.32; p = 0.034), but not with dyslipidemia (p = 0.281) or hyperglycemia (p = 0.379).

people. Only eight articles met the eligibility criteria of the review. An association between the exposure variable and some cardiometabolic outcome was observed in seven articles. However, the data suggest the absence of an association with hyperglycemia, were inconclusive for altered lipid profile and divergent for high blood pressure, and indicated an association with insulin resistance and metabolic syndrome only in boys.

The number of daily steps is a simple measure of the total volume of physical activity, which can be obtained objectively with a pedometer, a small, noninvasive inexpensive and easy-to-use device[10]. Furthermore, studies comparing pedometer and accelerometer estimates of physical activity have suggested a good correlation with total physical activity volume[10,14,27]. Despite these advantages, the association of step count with cardiometabolic outcomes in childhood and adolescence is poorly understood. Most studies investigated overall physical activity or its domains and sedentary behavior as exposure variables rather than step count, a fact impairing the comparison of our findings with other studies.

Andersen et al.[5] conducted a review on the relationship between physical activity (evaluated by self-report or accelerometry) and cardiometabolic risk factors in children. Studies with different designs (observational, experimental, and reviews) were included and the findings indicated an association of physical activity practice with lower blood pressure levels and a healthy lipid profile. The association with metabolic syndrome was inconclusive in the studies that used self-report to measure physical activity, while a more consistent association was observed when accelerometry was used to estimate physical activity[5]. With respect to systematic reviews and meta-analysis of intervention studies, the collected body of evidence indicates that an increase in physical activity is consistently associated with improvement in the cardiometabolic profile and with a reduction in the risk of developing metabolic syndrome and insulin resistance in young people[6-8]. Regarding sedentary behavior, Tremblay et al.[28] suggested in a systematic review that a decrease in any type of sedentary time (e.g., TV, computer, video game) is associated with a lower cardiometabolic risk in young people. In particular, evidence suggests that an additional two hours of watching TV per day is associated with a reduction in physical and psychosocial health, while a decrease in the time spent in this activity results in a lower body mass index[28].

Some methodological aspects of the studies included in the review should be addressed. The sample was smaller than 500 subjects in more than 70% of the studies and only one evaluated more than 1,000 participants. This aspect is relevant because small sample sizes reduce the power of statistical association analysis between the exposure and outcome. The three longitudinal studies selected used the same database[20-22], as did the two cross-sectional studies[23,24]. This fact may have overestimated the results of association analysis in these studies, especially for insulin resistance and metabolic syndrome. The way the outcomes were analyzed is another factor that can affect the associations with step count. In the longitudinal studies, the outcomes were analyzed continuously, while the outcomes were categorized in the cross-sectional studies. Although categorization is interesting because it discriminates risk groups, there is no consensus in the literature on the criteria used to classify different cardiometabolic outcomes. For example, different cut-offs can be used to classify lipid profile components (triglycerides, total cholesterol and fractions)[29,30] or to diagnose metabolic syndrome[26,31]. In other words, in addition to reducing the power of association analysis, outcome categorization can impair comparison even between studies that investigate the same outcome. According to Andersen et al.[5], more consistent associations with physical activity are observed when the cardiometabolic outcomes are analyzed as continuous variables.

With respect to the devices and procedures used for the measurement of step count, three studies did not report information about the validity of pedometers for the pediatric population[23-25]. The lack of this information is a matter of concern given that validity corresponds to the degree to which the device is able to determine the true value of what is being measured. Regarding the time of pedometer use, seven studies monitored the number of steps for one week[19-25] and one study for four days[18]. Tudor-Locke et al.[32] suggested the measurement for only three days to correspond to the average daily steps of a person (r=0.80). On the other hand, Clemes et al.[10] reported that the ideal number of days for monitoring step count in the pediatric population is still undetermined, although the usual number is seven consecutive days. Although the results of the reactivity of children to sealed or unsealed pedometer monitoring are conflicting[10], it should be noted that three of the selected studies used unsealed pedometers to monitor the number of steps of young people[19,23,24]. In all cross-sectional studies, step count was categorized for association analysis and different classification criteria were used. Two studies[23,24] classified the number of steps according to the cut-off values proposed by Vincenti and Pangrazi[33], one[19] used the criteria of Duncan et al.[34], one[25] used quartiles, and one[18] classified the sample based on quartiles and on the recommendation proposed for adults (10,000 steps per day). The lack of consensus on the classification of step count in young people impairs the comparison among studies and represents an important challenge for future research in this field.

In addition to the methodological limitations of the selected studies, another factor that may explain the lack of more consistent associations between pedometer-measured physical activity and cardiometabolic outcomes in young people is the limitation of pedometers, which evaluate only "walking" activity, i.e., the number of steps. Thus, this device does not take into consideration the intensity or duration of activities. This issue is more relevant among children who perform many short-duration intermittent activities in daily life. Recording only the number of steps may therefore not express the level of physical activity of this population group.

The inclusion of studies with repeat samples or those using the same database to compose the sample might be a limitation of this review because of the possible overestimation of associations. However, these studies were maintained for two reasons: 1) the descriptive design of the present review, with no intention to perform a meta-analysis, and 2) the small number of articles that met the eligibility criteria. Another limitation was the fact that studies published before 2000 were not included. However, research of physical activity by motion sensors and of its association with cardiometabolic risk factors intensified after this year. Nevertheless, the articles included in this review were only published starting in 2009. The absence of quality analysis of the articles is another potential limitation.

CONCLUSION

The results of this systematic review of the association between step count and cardiometabolic risk factors in young people were inconclusive, despite the observation of associations with some cardiometabolic outcome in seven of the eight studies analyzed. The small number of articles that met the eligibility criteria and the different methodological problems of the selected studies were the main factors limiting inferences. Observational studies with a longitudinal design (cohort and case-control), larger sample size and accurate methodological control for the assessment of exposures and outcomes are necessary to determine the association between step count and cardiometabolic risk factors in children and adolescents.

COMPLIANCE WITH ETHICAL STANDARDS

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Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conceived and designed the experiments: APG, TMBQ, LRS. Performed the experiments: APG, TMBQ. Analyzed the data: APG, TMBQ. Contributed reagents/materials/analysis tools: APG, TMBQ, LRS. Wrote the paper: APG, TMBQ, LRS.

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