Review

Methods for measuring physical activity in children and their relationship with nutritional status: a narrative review

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Summary

In recent decades, overweight and obesity have become a global epidemic that affects not only the adult population but also children and adolescents. In Spain the prevalence reaches 46%, with a greater presence in men. On the other hand, in some countries of Latin America the rates are close to 50% of overweight and obesity in children between 5 and 9 years old. Excess weight negatively affects the motor function of a child, causing a low ability to develop basic motor skills such as balance, gait and jumping. Also, overweight and obesity in children have been associated with a low motor repertoire, which translates into a delay in psychomotor development. These alterations influence the low motivation and interest in physical activity (PA) and less integration in games and sports practices. PA can be measured in different methods in children, the most commonly used instruments being pedometers, accelerometers and self-report questionnaires. The relationship between the level of PA and the nutritional status behaves in an inverse manner, that is, those with a higher BMI have low levels of PA. This occurs mainly in children older than 7 years old, since in children of lower ages this relationship is inconsistent. On the other hand, it has been possible to demonstrate the negative effects of low PA on motor skills and physical fitness in children, which is exacerbated by overweight and obesity in children. The regular performance of PA favours the development of motor skills in children with excess weight, favouring a more active participation in sports activities. Consequently, the development of effective intervention programs specifically targeting motor skills and physical fitness could help break the vicious circle of obesity and reduce the prevalence of comorbidities.

Key words:
Overweight. Obesity. Physical activity. Children.

Métodos de medición de la actividad física en niños y su relación con el estado nutricional: una revisión narrativa

Resumen

En las últimas décadas, el sobrepeso y obesidad se han convertido en una epidemia mundial que afecta no solo a la población adulta sino también a niños y adolescentes. En España la prevalencia alcanza el 46%, con mayor presencia en hombres. Por otro lado, en algunos países de América Latina, las tasas se acercan al 50% del sobrepeso y obesidad en niños de 5 a 9 años. El exceso de peso afecta negativamente la funcionalidad del niño, causando una baja capacidad para desarrollar habilidades motoras básicas como el equilibrio, marcha y salto. Además, el sobrepeso y obesidad en niños se han asociado con un bajo repertorio motor, que se traduce en un retraso del desarrollo psicomotor. Estas alteraciones influyen en la poca motivación e interés en la actividad física (AF) y en una menor integración en juegos y prácticas deportivas. La AF puede medirse con diferentes métodos en niños, siendo los instrumentos más utilizados los podómetros, acelerómetros y cuestionarios de autoreporte. La relación entre el nivel de AF y el estado nutricional se comporta de manera inversa, es decir, aquellos con un IMC más alto tienen niveles bajos de AF. Esto ocurre principalmente en niños mayores de 7 años, ya que en niños de edades más bajas esta relación es inconsistente. Por otro lado, ha sido posible demostrar los efectos negativos de bajo nivel de AF en las habilidades motoras y condición física en niños, que se ve agravada por el sobrepeso y obesidad. La práctica regular de AF favorece el desarrollo de habilidades motoras en niños con exceso de peso, favoreciendo una participación más activa en actividades deportivas. En consecuencia, el desarrollo de programas de intervención eficaces dirigidos específicamente a las habilidades motoras y condición física podría ayudar a romper el círculo vicioso de la obesidad y reducir la prevalencia de comorbilidades.

Palabras clave:
Sobrepeso. Obesidad. Actividad física. Niños.

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Introduction

In recent decades, overweight and obesity have become a global epidemic that affects not only the adult population but also children and adolescents. In 2010, the prevalence of overweight and obesity among pre-school children increased by 60% since 1990, affecting some 43 million children worldwide[1]. In the United States of America, 29% of children and adolescents have excess weight[2], while in Spain the prevalence reaches 46%, with a greater presence in men[3]. On the other hand, in some countries of Latin America the rates are close to 50% of overweight and obesity in children between 5 and 9 years old[4].

Excess weight has a negative effect on a child's motor function. Studies have described that children who are overweight and obese have a low ability to develop basic motor skills such as balance, gait and jumping[5-8]. Also, overweight and obesity in children have been associated with a low motor repertoire, which translates into a delay in psychomotor development[6,9]. These changes influence the low motivation and interest in physical activity (PA) and less integration in games and sports practices[6,10]. It has been described that the motor capacity improves with the regular practice of PA, where the motor performance is related to the quantity and diversity of motor proposals that are offered to children[10].

For its part, PA plays an important role in the prevention of overweight and obesity in childhood and adolescence, and in reducing the risk of obesity in adulthood[11]. Although the levels of PA in adolescents have been studied more frequently, those of children have not received as much attention[12]. Currently, the most important official reports on PA levels in children have been based on data obtained through pedometers, accelerometers and self-report questionnaires. Many countries and organisations have developed PA recommendations for children and young people of school age[13]. With few exceptions, these countries and organisations recommend that children and adolescents should participate in at least 60 minutes of moderate to vigorous daily PA[14,15]. It has been seen that children who have higher levels of PA have a better physical fitness and greater development of motor skills[15]. Therefore, studying the levels of regular PA and its consequences in children has become a major challenge in both health and research.

Methodology

Search strategy

In the period between October 2018 and February 2019, an exhaustive search was performed of the scientific literature concerning the existing links between the PA level and the nutritional status in children. To discover and obtain the academic articles, PubMed, Scopus, Sciencedirect, SciELO and Ovid databases were used.

Combinations of the following key terms were used to search the above databases: PA level terms ("physical activity", "exercise"); Children terms ("children", "child", "schoolchildren" and "creschool child"); general measurement terms ("measures", "measurement", "instruments", "tools", "tests", "assessment", "testing"); nutritional status terms ("obesity", "pediatric obesity", "overweight", "body mass index"); and functional terms: ("fitness", "motor development", "motor skills").

Study selection

The articles compiled are in Spanish, English and Portuguese. The selection was performed using three filters: 1) The articles taken from the database were initially selected for their titles, ruling out publications that were clearly not related to the study objective; 2) Next, the abstracts were read, selecting the studies that were directly related to the central interest of this work, identifying the publications that appeared in more than one database. Then the complete texts of the potential articles were recovered to be put through the final filter; 3) In this phase a critical reading, analysis and assessment was performed on each study, to check the methodological truthfulness and quality. Each study was assessed independently by at least 3 of the authors. Finally, to develop each component of this study, publications with the highest relevance and importance were included.

Results

Next the exhaustive review of the literature obtained during the search of the consulted databases uncovered a total of 115 potentially eligible articles, of which a sample of 39 articles was taken of those in which the authors backed up their findings with the best theoretical bases, as well as using effective methodology and having greater scientific relevance.

Instruments to quantify the level of PA in children

Pedometry

Consists of counting the number of steps a subject gives through an internal sensor that detects accelerations and decelerations in a single direction of movement when taking a step[16]. In general, it provides a measure of the total PA in a given period of time, however it is unable to measure intensity, record activities such as cycling and detect increases in energy expenditure due to transport of objects or walking and running on a slope[16]. Recent studies have summarised the considerations for evaluating PA using pedometers in children[17-19]. These reviews have provided recommendations regarding the monitoring periods and the time of use of the pedometer. It has been suggested that it takes between 4 and 9 days to capture the usual activity in children and adolescents[19,20]. However, compliance decreases with increases in the monitoring period; therefore, it is more feasible to opt for 4 full days with at least 1 day of the weekend[17]. A problem related to the monitoring of the frame is the time of use of the pedometer. In monitoring studies, participants are usually asked to record in a diary the time of the morning the pedometer was placed, along with any time during the day they left. It has been recommended that in the monitoring studies the data of a particular day be excluded if a participant reports on the elimination of his pedometer for more than 1 hour on that day[17,21]. It is recommended to use from 3 years onwards regardless of their nutritional status[19,22], however most studies have evaluated children older than 5 years[19]. The recommendations establish that children of both genders should walk at least 12,000 steps/day to be classified as physically active[23]. In addition, Tudor-Locke *et al.*[24] have proposed different values for boys (15,000 steps/day) and girls (12,000 steps/day) in order to prevent childhood overweight and obesity, measured by body mass index (BMI).

Accelerometery

Accelerometers are the most used method to objectively quantify PA and have been used in different populations[25-27]. Accelerometers quantify movement over a period of time by measuring the frequency, duration, and intensity of the PA, as well as the PA patterns[26,27]. During the last few years there has been a great increase in the number and variety of PA monitors commercially available in the market. Accelerometers are reasonably reliable and valid measures of PA. Its small size makes it a practical and comfortable instrument to wear. Accelerometers can provide a comprehensive profile of the behaviour of the PA, describing the total amount and intensity of the PA, the when and how the PA accumulates, and when periods of inactivity occur[28]. However, they do not provide information on the type of activity and cannot estimate whether people are walking with or without a load[28]. Most appropriate, is that the accelerometer is worn for seven consecutive days, since the subjects do not follow the same pattern of PA every day. Other authors, however, indicate that 5 days is enough, including the weekend. In order to analyse the PA record and follow up, most authors agree that subjects must fill out a "record sheet" to supplement the data acquired by the accelerometers[28]. The use of accelerometery is a widely accepted form of objective monitoring of free-living PA in children with any nutritional status and it is recommended to use from 3 years onwards due to its simplicity in use, a relatively cheap economic cost and low physical load for participants[29-32].

Among the most commonly used models of accelerometers as PA measurement instruments, are ActiGraph and ActivPal. During the last 10 years, ActiGraph accelerometers (AM7164 or CSA, GT1M, GT3X and GT3X +) have been used to evaluate PA levels and sedentary behaviours at all ages. They are practical and widely used devices that measure accelerations (counts) and are generally worn at the waist with an adjustable strap. Although these devices are used in many studies, they still have some limitations. First, ActiGraph accelerometers do not measure posture, but measure PA and time without movement. Because these accelerometers use traditional vertical accelerations to define sedentary behaviour, the device can reliably detect dynamic events, but cannot distinguish between standing and sitting[33]. As a consequence, the periods of sitting and some standing are classified as sedentary behaviour[33]. Some studies classify standing still as a light PA because standing is related to the large muscles of the lower part of the body and, therefore, a distinction must be made with sedentary behaviour. A second limitation of these accelerometers is that several calibration studies have defined different cut-off points of the accelerometer to estimate time in sedentary behaviour in young children from 3 to 8 years old[34], therefore, there is no clear consensus in this regard. On the other hand, ActivPAL devices are also relatively new accelerometers that are used to measure the activity of daily living and sedentary behaviour in different age groups. It is a small, single-unit, lightweight PA monitor and used at the thigh level. With this accelerometer the position and activity of the limbs can be detected, which gives rise to different postures that will be determined in three different categories depending on the inclination of the thigh (sitting/lying down, standing and walking). Because accelerometery is not able to discriminate between activities when there is no movement (for example, between sitting and standing), the inclination and/or rotation of the thigh could indicate the difference between sitting and standing[35].

Regarding cut-off points to classify PA levels in children, Riddoch *et al.*[36] revealed that 3 METs were equivalent to roughly 1000 counts per minute (cpm) among 9-year-old children, establishing it as the cut-off score to discriminate active and inactive children. However, Puyau *et al.*[37] defined physically active children as activity counts above 3200 cpm. The lack of standardization regarding how accelerometers are used, which outcome measures are used and how the output is interpreted[38]. This limits comparability between studies and the accumulation of knowledge relating to children's activity[38].

Self-report questionnaires

PA can be measured objectively by different methods, requiring special devices that can be very expensive and impractical for population studies in children[39]. Therefore, subjective methods using questionnaires represent a viable tool for studies based on large populations[40,41]. The self-report questionnaire used internationally to estimate the level of PA is the *Physical Activity Questionnaire for older Children* (PAQ-C). This is a self-administered questionnaire designed to measure moderate to vigorous PA performed in the last 7 days in children and adolescents[42,43]. It consists of ten items, nine of which are used to calculate the level of activity and the other item assesses if any illness or other event prevented the child from doing their regular activities in the last week[42]. The administration time of the instrument is around 20 minutes[44]. The overall result of the questionnaire is a score of 1 to 5, so that higher scores indicate a higher level of activity. The PAQ-C in its original version has shown a good internal consistency, test retest reliability, and has been shown to correlate with other instruments that measure PA as the accelerometer[45]. The recommended ages for the administration of PAQ-C range between 8 to 12 years and any nutritional status[46]. After 12 years there are other questionnaires such as Physical Activity Questionnaire for adolescents (PAQ-A)[44]. Due to the nature of children's activity and children's limited ability for recall, objective techniques are recommended for the assessment of their PA in children under 8 years[38]. For the PAQ-C the cut-off point near 2.75 has been suggested to discriminate between children with low and high PA levels[47].

Table 1 shows a comparative of the most used instruments to measure the level of PA in children.

Relationship between the level of PA and nutritional status in children

Among the main factors that influence the nutritional status of children, the level of PA is considered as one of the most determining[48,49], however, the information available is inconsistent and controversial regarding the relationship between the level of PA and nutritional status in children. There are studies that indicate that children who are overweight and obese have a low level of PA compared to their similar normal weight[48-54]. More active children present lower body fat percentage, as well as lower values of the BMI[55]. Muros *et al*. (2016), reported negative associations between the BMI and the percentage of

Table 1. Comparison of the instruments of measurement of physical activity in children.

	Pedometry	Accelerometery	Self-report questionnaires
Type of measurement	Direct	Direct	Indirect
Economic cost	Medium	High	Low
Evaluation time	4-9 days[19,20]	5-7 days[28]	20 minutes[44]
Recommended ages	From 3 years old onwards[19,22]	From 3 years old onwards[31,32]	8-12 years of age[46]
Advantage	Portable and objective method that allows to evaluate any type of population. In children, you do not need to be able to understand instructions or remember their activities[16].	Portable and objective method that allows to evaluate any type of population. In children, you do not need to be able to understand instructions or remember their activities[28].	Recommended for large populations for simplicity of application and time required for evaluation[38,44].
Disadvantage	Inability to measure intensity, record counts during cycling and record increases in energy expenditure due to carrying objects or walking/running uphill[42]. The display of the step counter in children can alter the measurement (it is recommended to 'blind' children to their scores by sealing the pedometers)[16,38].	Lack of standardization regarding how accelerometers are used, which outcome measures are used and how the output is interpreted[44]. This limits comparability between studies and the accumulation of knowledge relating to children's activity[38].	Its use depends on the ability of children and parents to remember their activities in the last 7 days[38].

fat with the level of PA measured through the PAQ-C in schoolchildren between 9 and 11 years old, that is, children who performed lower PA had a tendency to be overweight and obese[48]. In this same context, the systematic review carried out by Jimenez-Pavon *et al*. concluded that the high levels of PA measured with pedometry and accelerometery showed a protective factor in the development of corporal adiposity and childhood obesity[49]. Compared to non-obese children, obese children are less active and participate less in moderate and/or intense activities, with predominance of low intensity activities[56,57]. However, when it is considered that the chance for an obese child to be less active is twice higher than a normal weight children[55], this reinforces the hypothesis that the nutritional status can determine the level of the PA in obese children[49], and to make difficult to control the excessive body fat. This means that those children are less active than the obese ones, rather than being obese simply because they are less active. But it is worthy to mention the importance to practice physical activities, once active children from early ages are more likely to remain active in the adult age[55].

On the other hand, there are investigations that indicate that the level of PA does not influence the nutritional status in children[58-61]. Nava *et al*. (2011), evaluated children between 4 and 7 years old through a self-report questionnaire and found a significant relationship between the level of PA with eating habits, but not with nutritional status, which coincides with what was described by other authors[62,63]. The results in this age range are interesting because apparently the influence of PA does not manage to impact as strongly as it does in later stages of childhood. It has been reported that the first parameter that is modified with the change of eating habits is PA, and that the affectation of anthropometric parameters, such as BMI, manifests itself in prolonged periods of behavioural changes[62].

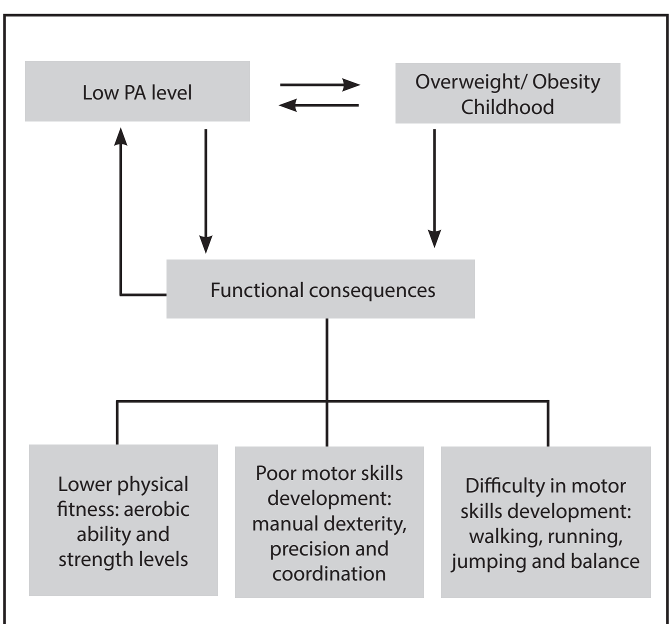
Impact of the low level of PA on motor function of children with overweight and obese

PA is often assumed to be causally related to motor function, suggesting that the most active individuals usually have a better physical fitness and motor ability. However, there are few studies that describe the functional consequences of low levels of PA in children. It has been seen that children under 12 years are overweight and obese, and also with a low level of PA have a lower cardiorespiratory fitness and lower levels of force upper and lower body compared to children with high levels of PA[48]. In this sense, the studies indicate that males have better physical fitness than girls in the variables of cardiovascular endurance, muscular strength, muscular endurance, speed and power[48,64]. With respect to motor development, it has been reported that children with low levels of PA have a poor development of motor skills such as control of objects, precision, coordination and postural balance[65,66]. Also, it has been described that children with low levels of PA have less ability in the development of motor skills such as walking, running and jumping[67-71]. Burgui *et al.* (2011), observed weak to moderate associations between PA and motor skills (that is, agility and balance) in pre-schoolers[72]. They found that higher baseline PA was associated with beneficial changes in motor skills at follow-up. This data suggest that the relationship between PA and motor skills is dominated by the impact of PA on motor skills[72]. This would be in accordance with the model of Stodden *et al*. (2008) that assumes that young children's PA might drive their development of motor skill competence[73]. This model suggests that in early childhood the relationship between PA and motor skills is still weak, but strengthens over time[73]. It appears plausible to argue that in young children, initial high motor skills performance levels per se do not guarantee a more active lifestyle, but that there is a need to continuously promote PA throughout childhood[72].

Fang *et al*. (2017), indicated that PA was positively associated with agility, balance, and aerobic fitness[74]. Physical fitness among normal-weight preschool children was significantly better obese and overweight children were less physically active and had lower physical fitness than normal-weight children in comparison to their overweight counterparts[74]. Similar results were reported that obese and overweight children were less physically active and had lower physical fitness than normal-weight children[75]. Research has noted a gender difference in the relationship between fitness and PA level. In boys, it has been proposed that a high level of PA has a relationship with body fat, upper limb muscular strength, explosive strength, agility and aerobic fitness[74]. For girls, a high level of PA showed associations with balance, agility and aerobic fitness[74].

A hierarchical order of development of motor skills has been proposed that includes four levels: reflexes, fundamental motor skills, transitional motor skills and specific skills of the sport[76]. The progression through each level occurs over time as a result of growth, maturation and experience. However, failure to achieve optimal competencies in basic and transitional motor skills limits the development of PA and, consequently, promotes the development of overweight and obesity in children[69,70,76]. Therefore, low levels of PA during childhood combined with excess weight contribute to poor physical fitness, and reduce confidence in the motor skills of these children to participate in sports and PA[77]. In contrast, the improvement of motor skills has the potential to improve children's motivation to participate in PA due to better self-esteem and greater fun, which could help break the vicious circle of obesity (Figure 1)[77,78].

Figure 1. Functional consequences of the low level of PA and its relationship with childhood overweight and obesity.



Although several investigations have shown that an PA program improves motor skills and physical fitness in children[79-84], there are few studies that have analysed the effects of PA on motor function, specifically in groups with excess weight. Among the interventions through PA in obese children, it has been seen that in 13 weeks, with sessions of 3 times per week, the motor skills improved, specifically, precision skills, manual dexterity, coordination and balance[85]. While other authors have proposed that intervention programs between 8 and 9 months (2-3 times per week) improve motor skills such as walking, running and jumping in children with overweight and obesity[86-88]. Consequently, PA can positively impact the motor function of overweight and obese children, helping to reduce the presence of comorbidities[89].

Conclusions

PA can be measured in different methods in children, the most commonly used instruments being pedometers, accelerometers and self-report questionnaires. Due to their portability, objectivity in measurement and consensus on cut-off scores to classify PA levels, pedometers seem to be the most recommended measurement method in children of all ages. Although acceleremotres are an alternative that delivers a greater number of variables, in children there is little consensus regarding cut-off scores to determine the PA level. For its part, the self-report questionnaires are the most economical and simple alternative, in children under 8 years of age their use is not recommended.

The relationship between the level of PA and the nutritional status behaves in an inverse manner, that is, those with a higher BMI have low PA levels. This occurs mainly in children older than 7 years, since in children of lower ages this relationship is inconsistent. On the other hand, it has been possible to demonstrate the negative effects of low PA on motor skills and physical fitness in children, which is exacerbated by overweight and obesity in children. The regular performance of PA favours the development of motor skills in children with excess weight, favouring a more active participation in sports activities. Consequently, the development of effective intervention programs specifically targeting motor skills and physical fitness could help break the vicious circle of obesity and reduce the prevalence of comorbidities.

Conflict of interest

The authors do not declare a conflict of interest.

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