European Psychomotricity Journal, 2014; 6; 1, 52-59 SciPsyMot-Hellas EPJ

European Union
European Social Fund
OPERATIONAL PROGRAMME EDUCATION AND LIFELONG LEARNING investing in knowledge society
MINISTRY OF EDUCATION & RELIGIOUS AFFAIRS MANAGING AUTHORITY
NSRF 2007-2013 programme for development
EUROPEAN SOCIAL FUND
Co- financed by Greece and the European Union

REVIEW ARTICLE

A review of the relationship between physical activity and motor proficiency in children

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Abstract

This review examined the associations of physical activity (PA) and motor proficiency (MP) in children. The 14 selected studies contained a variety of motor ability tests and the PA measured with the use of accelerometers, pedometers and questionnaires. These studies provided various ways of estimation of PA and MP. Gender differences appeared in many studies for MP and PA but in general findings suggest that high time spent in sedentary behavior was a predictor of low motor coordination and MP is a significant predictor of PA in children. Finally are presented the limitations of the studies with the purpose to provide more valid and accurate measures of PA and MP in the future.

Keywords: Childhood, physical activity, motor proficiency.

Introduction

Worldwide the decrease of physical activity (PA) and the increase of sedentary behavior are dramatically associated with the rise in childhood obesity (WHO 2010; WHO 2008-2013). Obesity in youth has been correlated with risks of hypertension, diabetes type 2, bad psychosocial consistence, ill-favored lipid profile and early atherosclerotic lesions (Must & Straus 1999; Reilly 2003; Speiser, 2005; WHO 2000) and also is known to correlate with adult obesity (Williams, 2001). Nevertheless, conservation of ideal body weight is an operation of equal energy intake and expenditure. Since PA is a potential factor associated with weight status, researchers interested in the relationship between PA and children body composition (Wilmore 1994).

PA is defined as any bodily movements produced by skeletal muscles that result in energy expenditure (Caspersen, 1985; Raustorp 2004,). PA commonly is assessed by the use of questionnaires, accelerometers or pedometers. There are plenty of benefits which resulting of an active lifestyle which is recognized even for young population not only in physical but also in social and psychological health (Strong, 2005). Public health PA guidelines recommend an amount of PA in time or in steps for children, adolescents and there is growing emphasis in creating specific guidelines for preschool children (Timmons, 2007). Participation in PA results with

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better proficiency in motor skills, but lower level of motor proficiency is correlated with lower levels of activity (Okely, 2001; Williams, 2008; Wrotniak, 2006).

Fundamental movement skills (FMS) are presented as the building blocks for more multiplicative movement skills and demanded for participation in structured and unstructured physical activities for preschool children, children, adolescents and adults (Gallahue, 2006; Payne, 1995). FMS distinguished in three categories which include, locomotor skills (e.g., running, hopping and jumping), manipulative or object-control skills (e.g., catching, throwing and kicking), and stability skills (e.g., balancing and twisting) (Gallahue, 2006; Payne, 1995). Furthermore, the practice of FMS in early years plays an important role on preschool curricula and also depicts to their physical, social and cognitive development (Payne, 1995). As children develop their FMS it appears to be profitable to provide appropriate encouragement, feedback and instruction (Gallahue, 2006; Jones, 2011).

The aim of this study was to tabulate the relationship of PA and motor skills in children in a survey of studies from the last 12 years.

Methods

To detect articles for the present review, searches were performed in PubMed and Wed of Science. Key terms consisted of a combination of organized and non-organized PA, sedentary behavior, motor coordination, motor skills, motor proficiency, fundamental movement skills, which were searched in conjunction with each term in the following group: preschool children; kindergarten; childhood. The articles were limited to those which (1) included children aged from 2 to 12.5 years old; (2) published in an English-language; (3) examined relationship between motor skills and PA; (4) published from the years 2002-2013. Additionally, were selected studies which assessed sedentary behavior and its association with motor skills. Finally, intervention studies and studies which deal with developmental coordination disorder in children were not included in the present review. The extended research and after taking into consideration all the above criteria, 14 articles were identified and included in this review.

Sample characteristics

Nine studies prosecuted in Europe, one in Australia, two in USA and two of them are not mentioned (Table 1). PA assessment completed by the use of accelerometer in eight studies, with questionnaires or self-reports in four studies and by using built-in-memory pedometer in two studies. The season of PA measurement are not mentioned in all of the selected studies. For motor proficiency (MP) four researchers preferred to investigate MP with Kiphard – Schilling body coordination test (Kiphard – Schilling body coordination test, KTK), two researchers preferred the Test of Gross Motor Development-2, four the short form of the first and second Bruininks – Oseretsky Test of Motor Proficiency, one the Movement Assessment Battery, one the Children's Activity and Movement in Preschool Study Motor Skill Protocol, one the Motorik Module test battery, and finally, one the predicted fundamental motor skill development by testing the overhand throwing and standing long jump.

Children's weight status was calculated using objectively measured height and weight to compute body mass index (BMI, kg/m^2) in 11 studies. Lopes (2012) used waist circumference and height to compute waist – to – height ratio. Additionally, Lopes (2011) calculated the sum of skinfolds and Houwen (2009) assessed body composition by using a leg-to-leg bioelectrical impedance analyzer. D' Hondt used bioelectrical impedance analysis to detect levels of body fat and finally, Logkizidou (2012) and as well as Raudsepp & Pall (2006) did not mention any anthropometric characteristic of subjects.

The most of the studies investigated the relationship between MP and PA. Papadopoulos (2008) compared the MP and PA of preschool children with different BMI. PA levels were examined in children with and without visual impairments (Houwen, 2009). Finally two study addressed the longitudinal relationship among MP and PA in children (D' Hondt, 2013; Lopes, 2011).

Results and Discussion

Of the 14 studies, six examined if there were differences in PA and MP between boys and girls (Lopes, 2012; Lopes, 2011; Cliff, 2009; Wrotniak, 2006). Three of them found differences between boys and girls and only one concluded that there were no differences between boys and girls in the association of running speed and agility, broad jump, or copying pencils with physical or sedentary activity (Wrotniak, 2006). Lopes (2012) observed that boys, aged 9-10 years old, spent less sedentary time than girls (73.90% and 77.20%, respectively) and on the other hand, girls spent fewer minutes in moderate to vigorous physical activity (MVPA) than boys. Additionally, girls displayed lower levels of MP with only 46.3% of girls and 59.3% of boys to presented normal or good MP. In both genders, the low sedentary group had significantly greater chances of providing high MP than the higher sedentary group, independent of PA (Lopes, 2012). Lopes (2011) examined the relationship among MP, physical fitness and PA in children who were followed longitudinally from 6 to 10 years and found boys had on average higher levels of MP and PA and greater scores on the fitness items than girls but for both genders presented a decrease in PA with age. Finally, in boys there were across year similar levels of MP while in girls tend to increase slightly from observations one to three and then decrease (Lopes, 2011). According to Kambas (2012) no statistical differences detected between girls and boys (5-6 years), in PA and also in motor proficiency. Cliff (2009) examined gender differences in cross-sectional relationship among FMS subdomains (locomotor skills, object-control skills) and PA in preschool children and highlight that FMS were positively correlated with PA in preschool boys and negatively correlated in preschool girls. Among boys, locomotor standard score was marginally associated with the percent of time in MVPA, object-control standard score was related to percent of time in moderate physical activity (MPA) and MVPA and was also related to percent of total PA. Finally for boys, Gross Motor Quotient (GMQ) was related to percent of time in MVPA, VPA and total PA. On the other hand, object-control standard score was not related to PA outcomes and also, both locomotor standard scores and GMQ were negatively related to percent of time in MVPA among girls. Although girls showed greater locomotor skills and subsequently for the GMQ than boys, girls locomotor skills held stronger negative

associations with habitual PA (MPA, MVPA) than object control skills (Cliff, 2009). Developmental level of overhand throwing, scores of accelerometer, rapid trunk-movement PA, and motor skill-related PA presented significantly higher in boys, while girls provided higher scores for lower-intensity PA such as limb movement and slow trunk movement and physical inactivity (Raudsepp & Pall, 2006).

Another question deals with how and if BMI reflect in MP and PA of children. D' Hondt (2013) found that there were a growing difference in KTK performance(s) of overweight and obese children versus normal weight children with increasing age and further demonstrated that participation in organized sports in a sports club predicts the level of gross motor coordination over a time frame of two years in children. Numez-Gaunaurd (2013) concluded that children who were obese demonstrated greater impairments in motor proficiency and participated in less physical activity than peers with healthy weight. Overweight and obese children presented lower daily steps taken and higher sedentary minutes than children with healthy weight and also BMI correlated negatively with BOT2-Short form (Numez-Gaunaurd et al., 2013). Papadopoulos (2008) found that PA was significantly lower in obese children than normal weight peers but there were no statistically significant differences in motor performance between normal, overweight and obese preschool children. Papadopoulos (2008) assessed PA with interview and as previously mentioned interviews, questionnaires or self-reports tend to overestimate time spent in vigorous physical activities and to underestimate time spent in unstructured daily physical activities which may explain the non-differences between BMI categories (Armstrong 2006). No significant associations were found between BMI, body fat, and any of the indices of physical activity for children without visual impairments (VI) (Houwen, 2009). On the other hand, BMI and body fat were significantly correlated with percentage time spent in sedentary and light activity, indicating that children with VI and higher BMI and body fat provided more sedentary behavior that children with lower BMI and body fat (Houwen, 2009). Additionally Houwen (2009) found that children with VI presented significantly lower PA, locomotor and object control scores than peers without VI which emphasize the need of developing programs for more active way of life for children with VI.

To the best of our knowledge, only two studies examined the relationship between MP and PA in preschool children by using pedometer for assessing PA. Kambas and colleagues (2012) concluded that motor proficiency was positively correlated with steps taken, aerobic steps taken and aerobic walking time. As more was the physical activity of preschool children as higher motor proficiency scores presented and additionally when this association examined by quartiles of motor abilities, children in the highest quartile were presented as the most physically active group (Kambas et al., 2012). Logkizidou (2012) found that there was statistically significant relation between motor skills performance and steps·day^{-1}. Significant differences presented in steps·day^{-1} among "below average" and "average" motor skill categories and also between "below average" and "above average". Preschool children which categorized at "above average" motor skill performance taken 13346 steps·day^{-1}, at "average" taken 9453 steps·day^{-1}, and finally at "below average" taken 6250 steps·day^{-1}.

Four studies assessed MP of children with KTK (D' Hondt, 2013; Lopes, 2012; Lopes, 2011; Graf, 2004). Graf (2004) found that children with the greatest extent of exercise (take part in athletic clubs and regular sport activity and irregular PA achieve the highest KTK results. Lopes (2012) concluded that a lot time spent in sedentary behavior was a predictor of low MP and emphasized the potential of discouraging sedentary behavior among children so to increase MP. Lopes (2011) suggested that MP and 1mile run/walk are an important predictor of PA in children 6-10 years of age because found that children with the greatest MP level had a higher level of PA. Finally, D' Hondt (2013) reported significant main effects of BMI groups for every single item as well as for total KTK, with overweight and obese children providing poorer performances than their normal weight peers both at baseline and follow-up.

On the other hand, Williams (2008) found that there was no association and also low, negative and non-significant correlation between motor skill performance scores, which assessed with CHAMPS Motor Skill Protocol, and sedentary or light PA in preschoolers. Significant positive correlations presented between motor skill performance and time spent in MVPA and VPA (Williams, 2008). Additionally there were no PA differences among tertiles of motor skill performance for object control scores and with respect to locomotor scores, children with high MP spent fewer time in sedentary activities than children in lowest tertiles and also spent more time in MVPA and VPA (Williams, 2008). In the same conclusion came another research which assessed MP with the Bruininks Oseretsky Test of Motor Proficiency-Short form (BOTMP) were presented significant associations between MP and PA in sedentary PA, MPA and MVPA (Wrotniak, 2006). Running speed and agility, broad jump and copying overlapping pencils were the items which associated with PA, while children who succeed greater on the visual-motor task of copying a picture and of overlapping pencils presented to provide higher percentage of time in MPA and MVPA than children who provided lower scores (Wrotniak, 2006). Raudsepp and Pall (2006) supported that developmental level of fundamental motor skills would be related with skill-specific outside-school PA but not with general level of PA of elementary school children. Finally, Fisher (2005), observed weak cross-sectional relationship between PA and FMS in preschool children. There were no significant correlation between FMS and light intensity PA but the correlation between FMS and time spent in MVPA provided a weakly but significantly positively correlation (Fisher, 2005).

In summary, findings stress the importance of promoting programs with main aim the development of FMS and PA in early years of life. Most authors suggested that high time sent in sedentary behavior was a predictor of low motor coordination and conversely MP is a significant predictor of PA in children.

Limitations

One of the most potential factors which may affected this review is the different way of the estimation of PA and MP. It's really difficulty to compare results from questionnaires, accelerometers and pedometers, first of all due to the fact that the way which data presented is not the same. For example pedometers provide data as steps per day and accelerometers categorize PA in intensity levels. Even thought the

most of the MP tests include same skills the categorization, classification and the calculation of the results may affect the generalization of data. Questionnaires or self-reports tend to overestimate time spent in vigorous physical activities and to underestimate time spent in unstructured daily physical activities (Armstrong, 2006). Accelerometers provide a better approach due to the way that they can classify PA in intensity levels (e.g. sedentary, light-intensity PA, moderate, vigorous) and also they offer the opportunity to collect and analyze an important amount of data. On the other hand, newest pedometer models have evolved from simple mechanical sensors to dual-axis acceleration sensors which can count steps horizontally and vertically. In comparison with accelerometers, pedometers are easily implemented and economically feasible for use in epidemic studies

Another measure of importance is that same authors did not specify the season their measurements were performed. Ambient temperature and rainfall have substantial effects on children's daily step counts and should therefore be considered when comparing physical activity across different locations or periods. For example, a 10^{o}C rise in mean ambient temperature has been associated with an increase in weekday steps ~1,700 steps and for week-end days ~3,400 steps in boys (Duncan et al., 2008).

In the most studies, body weight determined with BMI measurements which has been found previously unrepresentative of body weight and also the classification of BMI are not the same in all studies (Wells & Fewtrell, 2006). Only three studies used different measures to estimate body weight and body composition. Waist circumference and height, skinfolds and bioelectrical impedance were used only in three studies reducing in this way the error in assessing child body characteristics (Lopes, 2012; Lopes ,2011; Houwen, 2009).

ACKNOWLEDGMENT

Funding: This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Heracleitus II. Investing in knowledge society through the European Social Fund.

References

Armstrong, N., Welsman, J.R. (2006). The physical activity patterns of European youth with reference to methods of assessment. *Sports Medicine* 36(12), 1067-86.

Caspersen, C., Powell, K.E., Christensoon, G.M. (1985). Physical activity, exercise and physical fitness. Definitions and distinctions for health related research. *Public Health Reports* 100, 126-31.

Cliff, D.P., Okely, A.D., Smith, L.M., McKeen, K. (2009). Relationship between fundamental movement skills and objectively measured physical activity in preschool children. *Pediatric Exercise Science* 21, 436-449.

D'Hondt, E., Deforche, B., Gentier, I., De Bourdeaudhuij, I., Vaeyens, R., Philippaerts, R., Lenoir, M. (2013). A longitudinal analysis of gross motor coordination in overweight and obese versus normal-weight peers. *International Journal of Obesity* 37, 61-67.

Duncan, J.S., Hopkins, W.G., Schofield, G., Duncan, E.K. (2008). Effects of weather on pedometer determined physical activity in children. *Medicine & Science in Sports and Exercise* 40(8), 1432-8.

Fisher, A., Reilly, J.J., Kelly, L.A., Montgomery, C., Williamson, A., Paton, J.Y., Grant, S. (2005). Fundamental movement skills and habitual physical activity in young children. *Medicine & Science in Sports and Exercise* 37; 4, 684-688.

Gallahue, D.L., Ozmun, J.C. (2006). *Understanding motor development: infants, children, adolescents, adults.* 6th ed. Boston (MA): McGraw-Hill.

Graf, C., Koch, B., Kretschmann-Kandel, E., Falkowski, G., Christ, H., Coburger, S., Lehmacher, W., Bjarnason-Wehrens, B., Platen, P., Tokarski, W., Predel, H.G., Dordel, S. (2004). Correlation between BMI, leisure habits and motor abilities in childhood (CHILT-Project). *International Journal of Obesity* 28, 22-26.

Houwen, S., Hartman, E., Visscher, C. (2009). Physical activity and motor skills in children with and without visual impairments. *Med Sci Sports Exerc* 41; 1, 103-109.

Jones, R.A., Riethmuller, A., Hesketh, K., Trezise, J., Batterham, M., Okely, A.D. (2011). Promoting fundamental movement skill development and physical activity in early childhood settings: A cluster randomized controlled trial. *Pediatric Exercise Science* 23, 600-615.

Kambas, A., Michalopoulou, M., Fatouros, I.G., Christoforidis, C., Manthou, E., Giannakidou, D., Venetsanou, F., Haberer, E., Chatzinikolaou, A., Gourgoulis, V., Zimmer, R. (2012). The relationship between motor proficiency and pedometer-determined physical activity in young children. *Pediatric Exercise Science* 24, 34-44.

Logkizidou, K., Karagianopoulou, S., Andresaki, F., Nikolaidis, G., Skourti, K., Pavlidou, S., Fatouros, I., Pylianidis, T. (2012). Motor skills performance and pedometer-determined physical activity in young children. *European Phychomotricity Journal* 4; 1, 16-21.

Lopes, L., Santos, R., Pereira, B., Lopes, V.P. (2012). Associations between sedentrary behavior and motor coordination in children. *American Journal of Human Biology* 24, 746-752.

Lopes, V.P., Rodrigues, L.P., Maia, J.A.R., Malina, R.M. (2011). Motor coordination as predictor of physical activity in childhood. *Scandinavian Journal of Medicine & Science in Sports* 21, 663-669.

Must, A., Strauss, R. (1999) Risks and consequences of childhood and adolescent obesity. *International Journal of Obesity* 23 (suppl 2), 2S-11S

Numez-Gaunaurd, A., Moore, J.G., Roach, K.E., Miller, T.L., Kirk-Sanchez, N.J. (2013). Motor proficiency, strength, endurance, and physical activity among middle school children who are healthy, overweight, and obese. *Pediatric Physical Therapy* 25(2), 130-8.

Okely, A.D., Booth, M.L., Patterson, J.W. (2001). Relationship of physical activity to fundamental movement skills among adolescents. *Medicine & Science in Sports and Exercise* 33, 1899-1904.

Papadopoulos, D., Fatouros, I., Taxildaris, K. (2008). Motor proficiency physical activity and body mass index in preschool aged children. *European Phychomotricity Journal* 1; 1, 61-66.

Payne, G., Isaacs, D. (1995). *Human Motor Development*: A Lifespan Approach, 3rd ed. London: Mayfield Publishing Company.

Raudsepp, L., Pall, P. (2006). The relationship between fundamental motor skills and outside-school physical activity of elementary school children. *Pediatric Exercise Science,* 18, 426-435.

Raustorp, A., Pangrazi, R.P., Stahle, A. (2004). Physical activity level and body mass index among schoolchildren in south-eastern Sweden. *Acta Paedriatrica* 93, 400-404.

Reilly, J., Methven, E., McDowell, Z., Hacking, B., Alexander, D., Steward, L., Kelnar, C. (2003). Health consequences of obesity. *Archives of Disease in Childhood* 88, 748-752.

Speiser, P., Rudolf, M., Anhalt, H., Camacho-Hubner, C., Chiarelli, F., Eliakim, A., Freemark, M., Gruters, A., Hershkovitz, E., Lughetti, L., Krude, H., Latzer, Y., Lustig, R., Pescovitz, O., Pinhas-Hamiel, O., Rogol, A., Shalitin, S., Sultan, C., Stein, D., Vardi, P., Werther, G., Zadik, Z., Zuckerman-Levin, N., Hochberg, Z. (2005). *Journal* of *Clinical Endocrinology* & *Metabolism* 90, 1871-1887.

Strong, W.B., Malina, R.M., Blimkie, C.J.R. (2005). Evidence based physical activity for school-age yoyth. *Journal of Pediatrics* 146, 732-737.

Timmons, B.W., Naylor, P.J., Pfeiffer, K.A. (2007). Physical activity for preschool children-how much and how? *Canadian Journal of Public Health* 98(Suppl 2), S122-134.

Wells, J.C., Fewtrell, M.S. (2006). Measuring body composition. *Archives of Disease in Childhood*, 91, 612-617.

Williams, H.G., Pfeiffer, K.A., O'Neill, J.R., Dowda, M., McIver, K.L., Brown, W.H., Pate, R.R. (2008). Motor skill performance and physical activity in preschool children. *Obesity* 16, 1421-1426.

Williams, S. (2001). Overweight at age 21: the association with body mass index in childhood and adolescence and parents' body mass index. A cohort study of New Zealanders born in 1972-1973. *International Journal of Obesity* 25, 158-163.

Wilmore, J. (1994). *Exercise, obesity and weight control.* Washington DC: President's Council on Physical Fitness and Sports Research Digest; Series 1, No.6.

World Health Organization. Population-based strategies for childhood obesity: report of a WHO forum and technical meeting. Geneva: World Health Organization, 2010.

World Health Organization. 2008-2013 Action Plan for the Global Strategy for the Prevention and Control of Non-communicable Diseases. Geneva: World Health Organization, 2008.

Wrotniak, B.H., Epstein, L.H., Dorn, J.M., Jones, K.E., Kondilis, V.A. (2006). The relationship between motor proficiency and physical activity in children. *Pediatrics* 118, e1758-e1765.

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